AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523
BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY
BATCH 42

1. SUBJECT CLASSIFICATION

A. PRIMARY
Food production and nutrition

AF28-0000-G437

B. SECONDARY
Soil resources and management--USA

2. TITLE AND SUBTITLE
Reclamation and water management studies on coarse-textured saline-sodic soils in the San Luis Valley of Colorado

3. AUTHOR(S)

Franklin,W.T.; Whitney,R.S.

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1976	76 p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS

Colo.State

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*

9. ABSTRACT

A field experiment was conducted to study methods of reclaiming and managing the corase-textured saline-sodic soils in the Mosca-Hooper area of the San Luis Valley. The objectives of the experiment were to determine the effects of pre-leaching, amendments, and irrigation on soluble salt and exchangeable sodium removal and on subsequent crop growth at various water table levels. The experimental variables on the 96 plots in the investigation included: two water table levels: the application of 0.1% krilium, 1 and 4 tons per acre of gypsum, and 0.8 and 3.2 tons per acre of calcium chloride; two rates of leaching; various rates of surface irrigation; nitrogen fertilizer rates with and without phosphorus fertilizer; and subsoil tillage. Water table differences were achieved by pumping water from one area to lower the water table level and using the pumped water to raise the water table level in a second area. A water table difference was maintained but the levels in both areas fluctuated considerably from year to year. Crops grown on the plots to test the effects of the various treatments were: barley (1952, 1955, 1961-2); sweetclover (1953); potatoes (1954); alfalfa (1956-60); and oats (1963-4). Salts and sodium reaccumulated rapidly in the soil surface whenever the water table was raised to three feet or higher in the high water table area. These were reduced again by irrigation when the water table level lowered. Raising the water table level to three feet or higher during the cropping season resulted in increased crop yields and a greater response to amendment treatments. Incoporation of alfalfa into the crop rotation is recommended; it will contribute to an increased organic matter build-up and bring about an improvement in the physical condition of the soil.

10. CONTROL NUMBER
PN-AAC-779

11. PRICE OF DOCUMENT

12. DESCRIPTORS

Colorado,USA?	Saline soils
Field tests	Sodium
Irrigation	Solubility
Leaching	Water management

13. PROJECT NUMBER

14. CONTRACT NUMBER
CSD-2460 211(d)

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

RECLAMATION AND WATER MANAGEMENT STUDIES ON COARSE-TEXTURED SALINE-SODIC SOILS IN THE SAN LUIS VALLEY OF COLORADO

by

W. T. Franklin

and

Robert S. Whitney

Paper developed under support from U. S. Agency for International Development under contract AID/csd-2460. All reported opinions, conclusions or recommendations are those of the authors and not those of the funding agency or the United States Government.

Department of Agronomy
Colorado State University
Fort Collins, Colorado

October 1976

211(d)

TABLE OF CONTENTS

	Page
Acknowledgements	1
SUMMARY AND CONCLUSIONS	2
Removal and Control of Soluble Salts and Exchangeable Sodium	2
Crop Yields on the Soils	3
Recommendations for Reclaiming the Coarse-Textured Saline-Sodic Soils	4
INTRODUCTION	5
DESCRIPTION OF EXPERIMENTS	8
Objectives	8
Experimental Site and Soil Characteristics	9
Soil Sampling and Analytical Methods	10
Experimental Variables	10
EXPERIMENTAL RESULTS	14
Reclamation of the Soil	14
Crop Yields	26
DISCUSSION	44
Need for Reclamation and Feasibility	44
Water Table Control Requirements for Reclamation	45
Water Table Levels for Crop Growth and Salinity Control	47
Water Table Levels for Surface Irrigation	50
Management of Reclaimed Coarse-Textured Soils	50
REFERENCES	52
APPENDIX	53
Tables	53
Figures	73

RECLAMATION AND WATER MANAGEMENT STUDIES ON COARSE-TEXTURED SALINE-SODIC SOILS IN THE SAN LUIS VALLEY OF COLORADO

W. T. Franklin [1/] and Robert S. Whitney [2/]

Acknowledgements

The writers are indebted to several persons and agencies for their participation in the various phases and planning and carrying out this investigation. The study was supervised by R. Gardner until his retirement in 1954 and was carried out by L. C. Sonntag until 1955, both of the Colorado Agricultural Experiment Station. Assistance in planning the investigation was given by M. Fireman and R. C. Reeve, both formerly with the U. S. Salinity Laboratory; and W. H. Sweet, U. S. Bureau of Reclamation. Assistance in the engineering phases was given by W. E. Code (Irrigation Engineer Emeritus) and N. A. Evans, Colorado Agricultural Experiment Station. Financial assistance to initiate the studies was given by the U. S. Bureau of Reclamation, U.S.D.I.; the Western Soil and Water Management Section, A.R.S., U.S.D.A.; and the Mosca-Hooper Soil Conservation District. The U. S. Salinity Laboratory analyzed most of the soil samples during the first few years. The Mosca-Hooper Soil Conservation District furnished the land on which the investigation was conducted.

1/ Associate Professor (Soils), Department of Agronomy, Colorado State University, Fort Collins, Colorado.

2/ Professor and Head Emeritus, Department of Agronomy, Colorado State University, Fort Collins, Colorado.

SUMMARY AND CONCLUSIONS

A field experiment was conducted to study methods of reclaiming and managing the coarse-textured saline-sodic soils in the Mosca-Hooper area of the San Luis Valley. The objectives of the experiment were to determine the effects of pre-leaching, amendments, and irrigation on soluble salt and exchangeable sodium removal and on subsequent crop growth at various water table levels. The experimental variables on the 96 plots in the investigation included: 2 water table levels; the application of 0.1 % krilium, 1 and 4 tons per acre of gypsum, and 0.8 and 3.2 tons per acre of calcium chloride; 2 rates of leaching; various rates of surface irrigation; nitrogen fertilizer rates with and without phosphorus fertilizer; and, subsoil tillage. Water table differences were achieved by pumping water from one area to lower the water table level and using the pumped water to raise the water table level in a second area. A water table difference was maintained but the levels in both areas fluctuated considerably from year to year.

Crops grown on the plots to test the effects of the various treatments were: barley (1952), sweetclover (1953), potatoes (1954), barley (1955), alfalfa (1956-1960), barley (1961-1962), and oats (1963-1964).

Removal and Control of Soluble Salts and Exchangeable Sodium

In the low water table or pump-drained area where the water table was maintained below 5 feet, the application of either 4 tons per acre of gypsum or 3.2 tons per acre of calcium chloride combined with 30

acre-inches per acre of pre-crop leaching water plus additional irrigation with high calcium-magnesium water reduced salts and exchangeable sodium to non-saline and non-sodic levels to a 3-foot depth during the first cropping season. Raising the water table level, smaller rates of amendments, or lower leaching rates retarded salt and sodium removal. Complete reclamation was achieved with the high calcium-magnesium groundwater used for irrigation but it required a longer period of time.

Salts and sodium reaccumulated rapidly in the soil surface whenever the water table raised to 3 feet or higher in the high water table area. These reaccumulated salts and sodium were reduced again by irrigation when the water table level lowered.

Crop Yields on the Soils

At water table levels lower than 4½ feet during the early stages of reclamation, crop yields were undesirably low even though the salt and exchangeable sodium contents of the soil root zone were substantially reduced. Good stands of sweet clover and alfalfa were not obtained unless an excessive number of irrigations were applied at water table levels of 4½ feet or below. Dispersion and compaction of the soil resulting in shallow rooting depths apparently caused the low yields.

Raising the water table level to 3 feet or higher during the cropping season resulted in increased crop yields and a greater response to amendment treatments. The fluctuating water supplies in the area made maintaining a high water table during the cropping

season difficult to achieve, however.

Economically justifiable grain yields were obtained at water table levels lower than 4 1/2 feet after alfalfa was included in the rotation. Early planting of the grain crop, adequate fertilizer applications, and timely irrigations were necessary to achieve good yields under the lower water table conditions in the coarse-textured soils of low water-holding capacity.

Recommendations for Reclaiming the Coarse-Textured Saline-Sodic Soils

To obtain efficient removal of salt and exchangeable sodium from the soil root zone the water table should not be raised appreciably higher than 4 feet while leaching water is being applied. Water table control should be established if the water table is continuously above 4 feet. Pumping of groundwater to control the water table level and to supplement surface irrigation water supplies appears to be the most feasible procedure. Applying leaching and irrigation water with a sprinkler system to improve water application efficiency and timing of irrigation would increase the water-use efficiency in reclaiming and cropping the soils.

The amount of leaching water to be applied before establishing a crop should be determined not only on the basis of the salt to be removed but also on the basis of the exchangeable sodium to be removed from the top foot of soil to reduce the percentage to 10 or below. Exchangeable sodium removal is generally the governing factor. The amount of leaching to remove sodium will depend on the possible natural

gypsum content of the soil, the calcium and magnesium in the leaching water, or the amount of added commercial amendment which needs to be dissolved by the leaching water. These are best established by chemical tests of the leaching water used and of soil samples taken preferably from surface and sub-surface depths.

If flood irrigation is used after applying leaching treatments, the water table should be maintained at a 3 to 4 feet depth, if possible, to obtain a reasonably satisfactory crop stand and yield. Any salt or sodium reaccumulation during the cropping season can be controlled by pre-season or post-season leaching. Overdrainage during the cropping season, especially during the early reclamation stage, should be avoided. Excessive lowering of the water table below 4 feet will generally result in difficulties in establishing crop stands, uneconomically low crop yields, and inefficient surface irrigation.

An early incorporation of alfalfa into the crop rotation is strongly recommended. After it is once established, the deep-rooted alfalfa will yield well under relatively low water table conditions which will facilitate the completion of reclamation. Alfalfa will contribute to an increased organic matter build-up and bring about an improvement in the physical condition of the soil.

INTRODUCTION

Excessive accumulations of soluble salts and adsorbed sodium in the surface soils is a major problem in the San Luis Valley, especially in the eastern and northern sections. Several factors contribute to

these excessive salt and sodium accumulations. First, the climate is arid. It is characterized by a low annual rainfall of 6-8 inches, spread thinly throughout the year, and by rapid evaporation conditions. Evaporation of salt-bearing water from the surface concentrates and deposits the salts near the soil surface because the rainfall is insufficient to effectively leach the salts into the subsoil.

The low precipitation and high evaporation condition is aggravated by a high groundwater table. The topography and irrigation practices of the valley have resulted in a high water table and increasing salt and sodium accumulations. The area north of the Rio Grande is a "closed basin" (Powell, 1958). It has no natural drainage outlet and little or no irrigation water flowing into the area or diverted to the north side of the Rio Grande returns to the river. Most of the water diverted from the Rio Grande is used in the western part of the valley which is highly developed agriculturally. Some of the diverted water is transported via open canals to the eastern part of the valley for a limited amount of surface irrigation. The coarse-textured soils are underlain by impervious clay layers at various depths in the soil. These impervious layers have caused a shallow groundwater table to develop over the years of increased irrigated farming.

The valley floor, in general, slopes eastward about 6 feet per mile with a low-lying or "sump" area existing around the San Luis Lakes. Groundwater in the highly pervious gravelly subsoil moves toward the sump area carrying dissolved salts concentrated by evaporation and probably dissolved from the old lake bed salt deposits in the subsoil.

It is the general practice to "sub-irrigate" or keep the water table at approximately 2 or 3 feet from the soil surface whenever the diverted river water supply is favorable. Keeping the water table high is accomplished by applying an excess of surface irrigation or by running diverted water into a series of open ditches with check-dams placed at intervals. The water in the "sub-ditches" spreads laterally through the porous sub-soil to raise the water table.

During periods of river water shortages the sub-irrigation is supplemented by pumping the groundwater for surface irrigation. A periodic fluctuation in the water supply, with consequent periodic fluctuations in the groundwater table, has made it necessary to apply surface irrigation often enough to prevent extensive detrimental salt or sodium accumulations in the western part of the valley. Pump irrigation is not as highly developed in the eastern section. A less porous subsoil which makes pumping less efficient and more expensive and a somewhat more saline groundwater has retarded this development.

The supply of water diverted from the Rio Grande that reaches the eastern section usually is not sufficient to last throughout the cropping season. In many years the water supplied by ditches does not last beyond the month of June. This water contributes to maintaining a relatively high water table and increasing salinity problems but is insufficient to maintain a stable farming economy.

The reclamation of saline and sodic soils usually involves (1) lowering the water table when it occurs within the crop root zone since it is one of the main causes of excessive salt and sodium

accumulations, (2) when the soil does not contain natural gypsum applying an amendment to supply calcium to effect the removal of excess adsorbed sodium, and (3) removing excess soluble salts from the crop root zone by leaching or flushing them downward with irrigation water of a suitable quality.

A study of the feasibility of reclaiming and managing the typical coarse-textured saline-sodic soils of the Mosca-Hooper area was initiated in 1951 and was continued through 1964. This report deals with the effects of water table levels; amendment and leaching applications; irrigation and irrigation rates; and fertilizers and fertilizer rates on soil reclamation and the yield of crops.

DESCRIPTION OF EXPERIMENTS

Objectives

When the feasibility investigation of reclaiming the saline-sodic soils in the eastern part of the valley began in 1951, the following objectives were outlined:

1. To determine the optimum water table level or levels for efficient reclamation, surface irrigation, and crop growth.
2. To study the effects of leaching, soil amendments, and surface irrigation as methods for removing and controlling salinity and exchangeable sodium.
3. To determine the effects of irrigating with water from the shallow groundwater acquifer on soil salinity, exchangeable sodium, and plant growth.

4. To determine crop management practices which contribute to increased crop production while controlling excessive salts and sodium.

Experimental Site and Soil Characteristics

An 80-acre tract belonging to the Mosca-Hooper Soil Conservation District was chosen for field studies. The land is located 1 3/4 miles north and 1 3/4 miles east of Mosca (N½, SE¼, SE¼, Sec. 26, T40 N, R10 E, New Mexico Principal Meridian). The soil at the experimental site is lacustrine in origin and is quite representative of about 30,000 acres of land in the area.

The soil texture ranges from a sandy loam to a gravelly loamy sand in the surface and ranges from a sandy clay loam to a gravelly loamy sand in the subsurface. As an average, the surface 18 inches in the plot areas contained about 20% gravel, 68% sand, 8% silt, and 4% clay. Considerable variability in texture was found below 18 inches in the plot areas.

The average initial salt and exchangeable sodium status of the soil is shown in Table 1.

Table 1. Average soluble salt and exchangeable sodium in the soil, 1951.

Soil Depth	Soluble Salts	Exchangeable Sodium
in.	mmhos/cm.	%
0 - 7	17.3	32
7 - 18	5.3	22
18 - 33	2.4	12

The greatest concentration of salts and exchangeable sodium occurred in the surface and decreased with depth. The soil contained trace to considerable amounts of natural soil gypsum in the soil surface. Gypsum analyses were not made for all plots so the true extent of the soil gypsum cannot be evaluated. Little or no natural gypsum was found below 7 inches.

Soil Sampling and Analytical Methods

Soil samples were taken from each plot in the experiment in 1951 prior to any reclamation treatment. A complete sampling was again made in 1954. Soil samples were taken only on a few selected plots in other years. The samples were generally taken in the fall after the crop had been removed. The soil sampling procedure consisted of compositing 4 borings from each plot at the 0-7, 7-18, and 18-33-inch depths.

The analytical methods used to determine soluble salts, exchangeable sodium and other soil properties were those described by Richards (1954). Soluble salt values for the soil samples are given in Appendix Tables 1a-1d. Exchangeable sodium percentages are summarized in Appendix Tables 2a-2d.

Experimental Variables

Water table levels

A comparison of two groundwater table levels was incorporated into the experimental plan (Appendix Figure 1). The water table was lowered in one area, containing 48, 20 by 20-foot "drained plots", by

pumping continuously during the cropping season from a well located centrally in the area. The water from the drained plot area was piped to a second area, approximately 500 feet distant, which also contained 48 plots. The well water was piped into an open sub-irrigation ditch completely surrounding the plot area. Thus raising the water table in the "subbed plots".

This system excercised some, but not complete control over the water table levels in the two plot areas. It initially was intended to keep the water table level at about 2 feet in the subbed area and below 4 feet in the drained area. An approximate 2-foot water table level in the subbed area was achieved only in 1952, 1953, late in the 1957 season, and early in the 1958 season. In other years lower snow packs in the mountains resulted in less water delivery and a general water table drop over the whole area. Thus the desired water table level could not be maintained in the subbed area and was far lower in the drained area than was anticipated. A difference of 3-5 feet between the two areas was maintained as long as the continuous pumping-sub-irrigation operation was carried out.

Continuous pumping during the cropping season was discontinued in 1959. A small difference in water table levels still occurred because the well was used for irrigating both areas as well as other experimental plots added in the vicinity. The water table levels for the years of experimentation are given in Appendix Table 3. These are shown for May 15 and October 1 dates to show the trend for the year in addition to a yearly average calculated from weekly readings between these dates.

Amendments and soil conditioner

Amendment materials and a soil conditioner were applied on 4 replicate plots in each water table level area in the spring of 1952. The amendment variables were : gypsum at the rate of 1 and 4 tons per acre and calcium chloride ($CaCl_2$) at the rates of 0.8 and 3.2 tons per acre (calcium content equivalent to that in the gypsum). The soil conditioner, krilium, was applied at 1000 pounds per acre (0.1% in the first 3 inches of surface soil). No further amendment or conditioner applications were made during the years of experimentation. The high gypsum application rate was applied on plots which contained natural soil gypsum in so far as possible.

Leaching rates

The experimental variables included two pre-leaching rates - 12 and 30 acre-inches per acre. Water from the well in the drained area was used for leaching. The leaching water was applied by intermittent ponding on the diked 20 by 20-foot plots (after the amendments were applied and worked into the soil).

In the spring of 1954 before the crop was planted, an additional 9 acre-inches of leaching water were applied on the plots which originally received 12 acre-inches.

Surface irrigation and water quality

Surface irrigation was applied uniformly on all plots in 1952-53-54, except that the amount was less in the subbed area. Irrigation variables, applied as such, were included in most years after 1954. The amount and number of surface irrigation applications for the years

of experimentation are summarized in Appendix Table 5. These are shown for crop irrigation and for post-harvest irrigation. Some years it was necessary to irrigate before planting the crop to increase surface moisture for germination. Pre-planting irrigation was considered as a part of crop irrigation. Post-harvest irrigation was necessary to establish sweetclover and alfalfa stands after barley was harvested and to maintain established alfalfa stands. A late October irrigation was effective for preventing winter-kill of the alfalfa.

The well water was considered to be of fair quality for leaching and irrigation. The salt content in the water was fairly high containing approximately 1 ton per acre-foot of dissolved solids (Appendix Table 4). The equivalent calcium plus magnesium to sodium ratio was 3 to 1 with a sodium adsorption ratio of about 2. According to the U. S. Salinity Laboratory water standards the water was considered to have a low sodium hazard to the soil. Also, water was found to be excellent for replacing adsorbed sodium in the soil because the calcium content alone in an acre-foot of water was equivalent to the calcium in approximately 1350 pounds of chemically pure gypsum. Little change in the ion content of the water occurred during the years of the investigation.

Fertilizers and fertilizer rates

A uniform application of fertilizer or fertilizers was made on all plots in most years. A fertility trial with barley was conducted in 1962. A history of the fertilizer applications is shown in Appendix Table 6.

Subsoil tillage

One-half of each plot area was chiseled in the fall of 1962. The soil was cross-chiseled with a 15-inch spacing between shanks to a depth of 30 inches.

Crops grown

The crops grown to test the effect of various treatments were as follows: 1952, barley planted with sweetclover; 1953, sweetclover; 1954, potatoes; 1955, barley planted with alfalfa; 1956 through 1960, alfalfa; 1961 and 1962, barley; and, 1963 and 1964, oats. Summaries of the yield results for the various treatments are given in Appendix Tables 7-19.

Experimental design

The experimental design (Appendix Figure 1) was a randomized block with the leaching and amendment treatments replicated 4 times in each of the two areas. When surface irrigation and fertilizer variables were applied, the data were analyzed as a split-plot design.

Statistical analyses of cropping data comparing yields in the drained plot area with the yields in the subbed plot area were not possible most of the years because the difference in error variance terms between the two areas was too great (as calculated by the chi-square test for homogeneity, Cochran and Cox, 1953).

EXPERIMENTAL RESULTS

Reclamation of the Soil

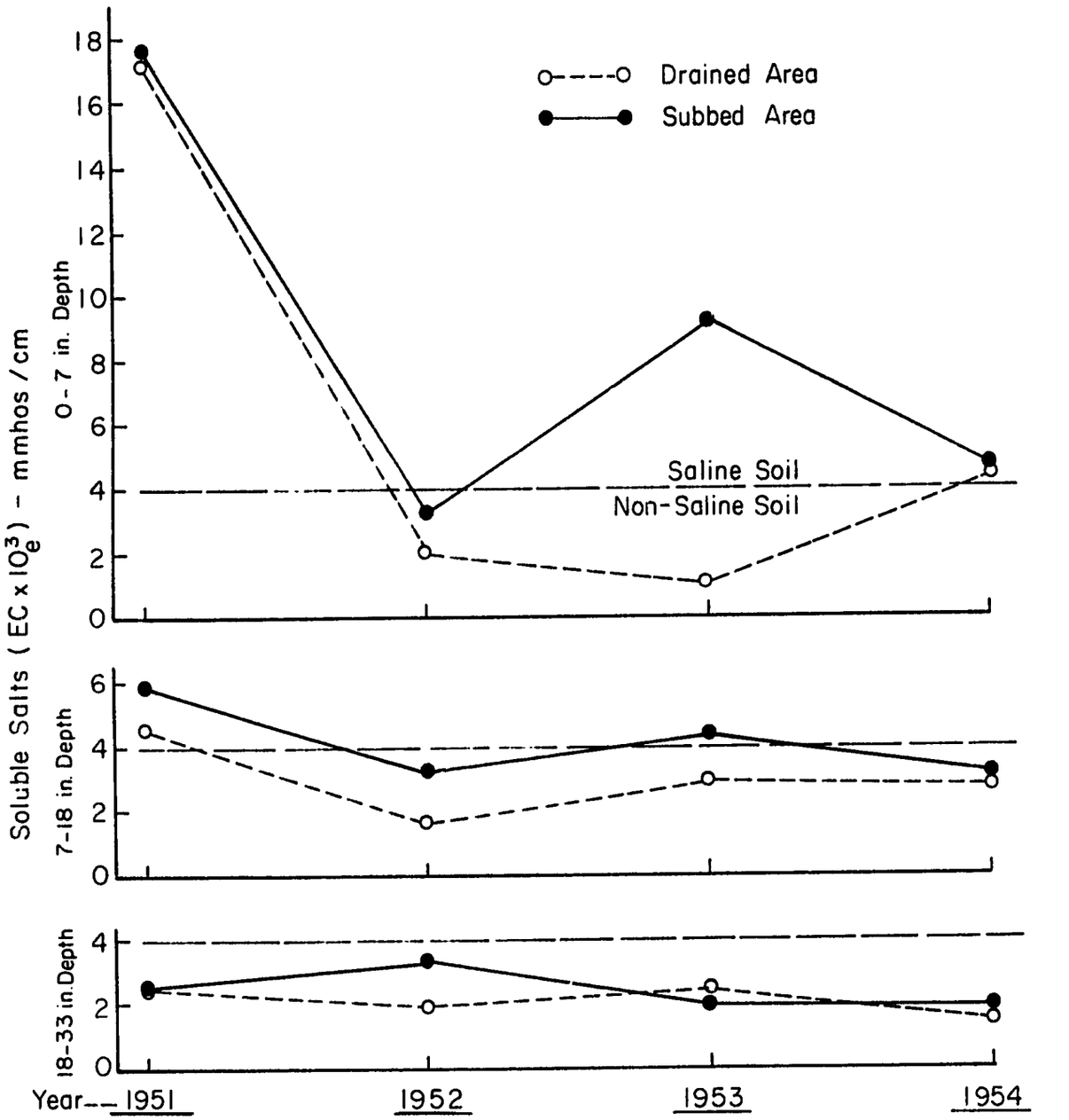
Effects of leaching, irrigation, and water table levels on soluble salt

and exchangeable sodium levels, 1951-1954

Soil samples were not taken immediately after the completion of leaching treatments and none were taken from the 12 acre-inch per acre (A-in./A.) leached plots in 1952. Thus the effects of the variable leaching rates on soluble salt and exchangeable sodium removal cannot be completely evaluated.

The combined effects of leaching and irrigation on the soluble salt (as measured by the electrical conductivity of the saturated soil extract) levels of plots leached with 30 A.-in./A. of water in the drained and subbed areas are shown in Figure 1. These salt levels are averages including all amendment plots sampled for the particular year. The amounts of irrigation and average seasonal water table depths shown at the bottom of the figure are presented to show the overall relationship between water table levels and irrigation on salt removal or reaccumulation. The 30 A-in./A. leaching treatment, applied in the spring of 1952 when the water table was at about a 5-foot depth, plus the approximate 2 A-ft./A. of surface irrigation water applied on the barley-sweetclover crops were quite effective in reducing the salt levels in both areas.

The salt reaccumulated considerably in the surface layer of the subbed area in 1953 where the water table level averaged 2.7 feet while cropping with sweetclover. A further reduction in the salt level of the drained area soil surface depth occurred where the water table depth averaged 5.4 feet.



	1952 Drained	1952 Subbed	1953 Drained	1953 Subbed	1954 Drained	1954 Subbed
Irrigation (A.-in./A.)	24	21	21	18	45	42
Water Table (ft.)	5.7	2.1	5.4	2.7	8.0	4.6

Yearly Total Amount of Irrigation and Average Seasonal Water Table Depths

Figure 1. The combined effects of 30 A.-in./A. pre-leaching and surface irrigation water on the average soluble salts in the drained and subbed areas with varying water table levels.

Row cropping the areas with potatoes in 1954 resulted in an increase of salts in potato row of the drained area whereas a reduction occurred in the subbed area. The potatoes were furrow-irrigated 15 and 14 times in the drained and subbed areas under water table levels considerably lower than the previous years. The salt levels at all soil depths were comparable in the two areas at the end of the 1954 season.

At the end of the 1954 season when soil samples from all plots were taken, no significant difference was found between the average electrical conductivity of the plots leached with 12+9 A-in./A. (2.78 mmhos/cm.) and with 30 A.-in./A. (2.84 mmhos/cm.) in the drained area (Appendix Table 1d). In the subbed area the average electrical conductivity of the 12+9 A-in./A. leached plots (3.05 mmhos/cm.) was significantly lower statistically than the 30 A.-in./A. leached plots (3.52 mmhos/cm.). The additional 9 A.-in./A. of water added on the original 12 A.-in./A. treatment in the spring of 1954 accounts for the lower average conductivity in the subbed area. However, the total amount of water added from leaching and irrigation was about the same for each pre-leaching treatment in each area at the end of the 1954 season. Therefore, the pre-leaching variable, in effect, had been cancelled.

The variation in the average exchangeable sodium percentage for the 30 A.-in./A. leached plots under varying water tables from 1951 through 1954 are shown in Figure 2. The initial exchangeable sodium levels in 1951 were higher at all soil depths in the drained area than

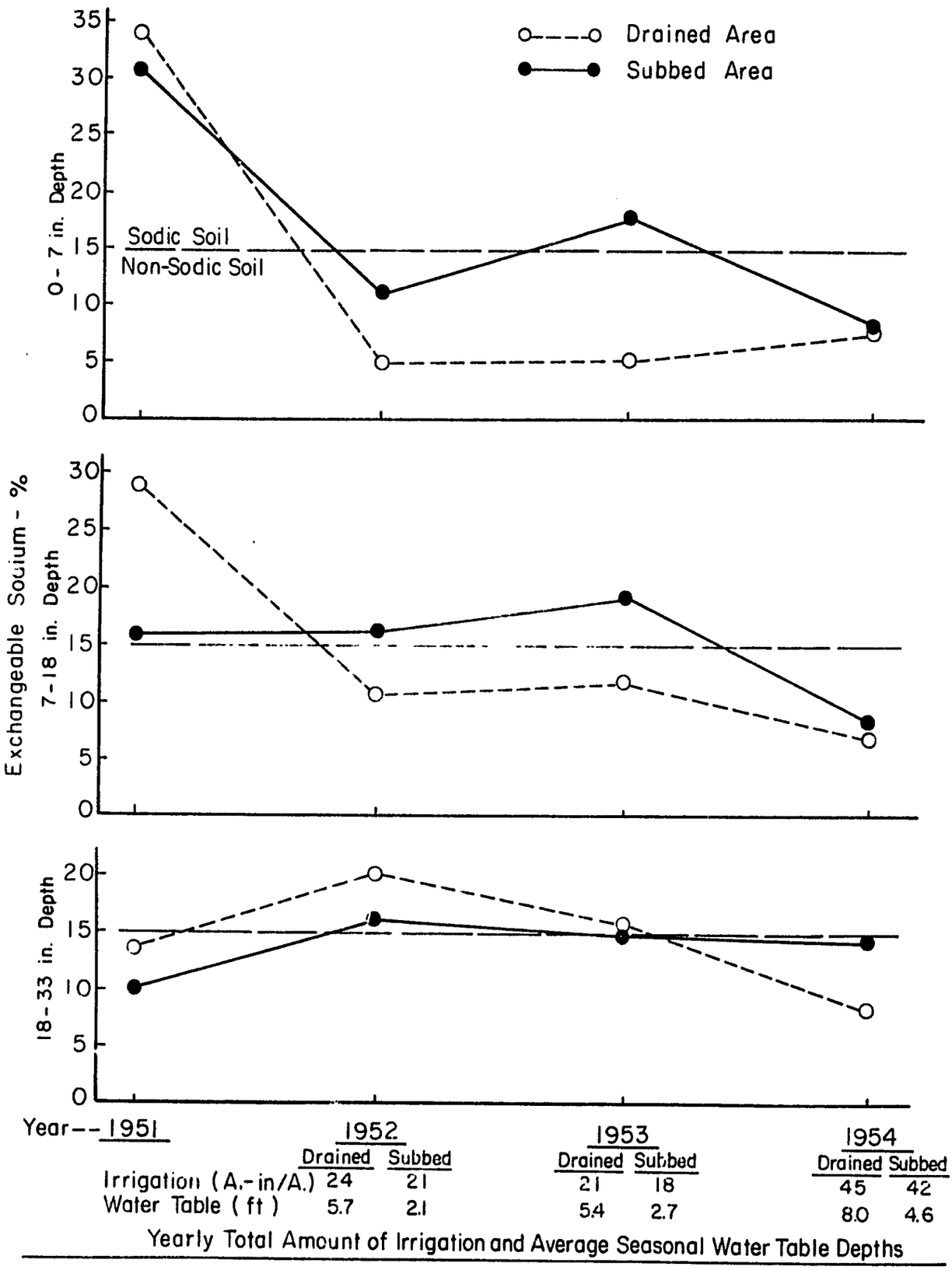


Figure 2. The effect of water table levels and irrigation on the average exchangeable sodium percentages of plots pre-leached with 30 A.-in./A. of water.

in the subbed area. Substantial exchangeable sodium reductions were obtained through a depth of 18 inches in the drained area in 1952, whereas a large reduction occurred only in the 0-7 inch depth of the subbed area. Exchangeable sodium reaccumulated in the subbed area in 1953 with the water table level averaging 2.7 feet but was reduced under the lower water table level in 1954.

Effects of amendments and leaching with high calcium-magnesium content groundwater on exchangeable sodium levels, 1951-1954

The exchangeable sodium percentages in the 3 soil depths sampled are shown in Figure 3. The total initial exchangeable sodium in the 0-33 inch soil depth and the losses or gains by years for the amendment and leaching treatments are shown in Table 2.

In general, the total amount and percentages of exchangeable sodium were higher initially and were more variable for a particular amendment treatment in the drained area than in the subbed area. Differences in the effects of the amendment treatments for removing exchangeable sodium cannot be completely evaluated because of the differences in initial exchangeable sodium between plots, because some plots contained considerable natural soil gypsum in the surface layer, and because the water used for leaching and irrigation contained considerable amounts of calcium and magnesium which were replacing sodium simultaneously with the calcium of the amendments.

As shown in Figure 3, the exchangeable sodium percentages in the drained area plots which received the 4 T./A. gypsum and 3.2 T./A. calcium chloride applications were reduced to very low levels by the

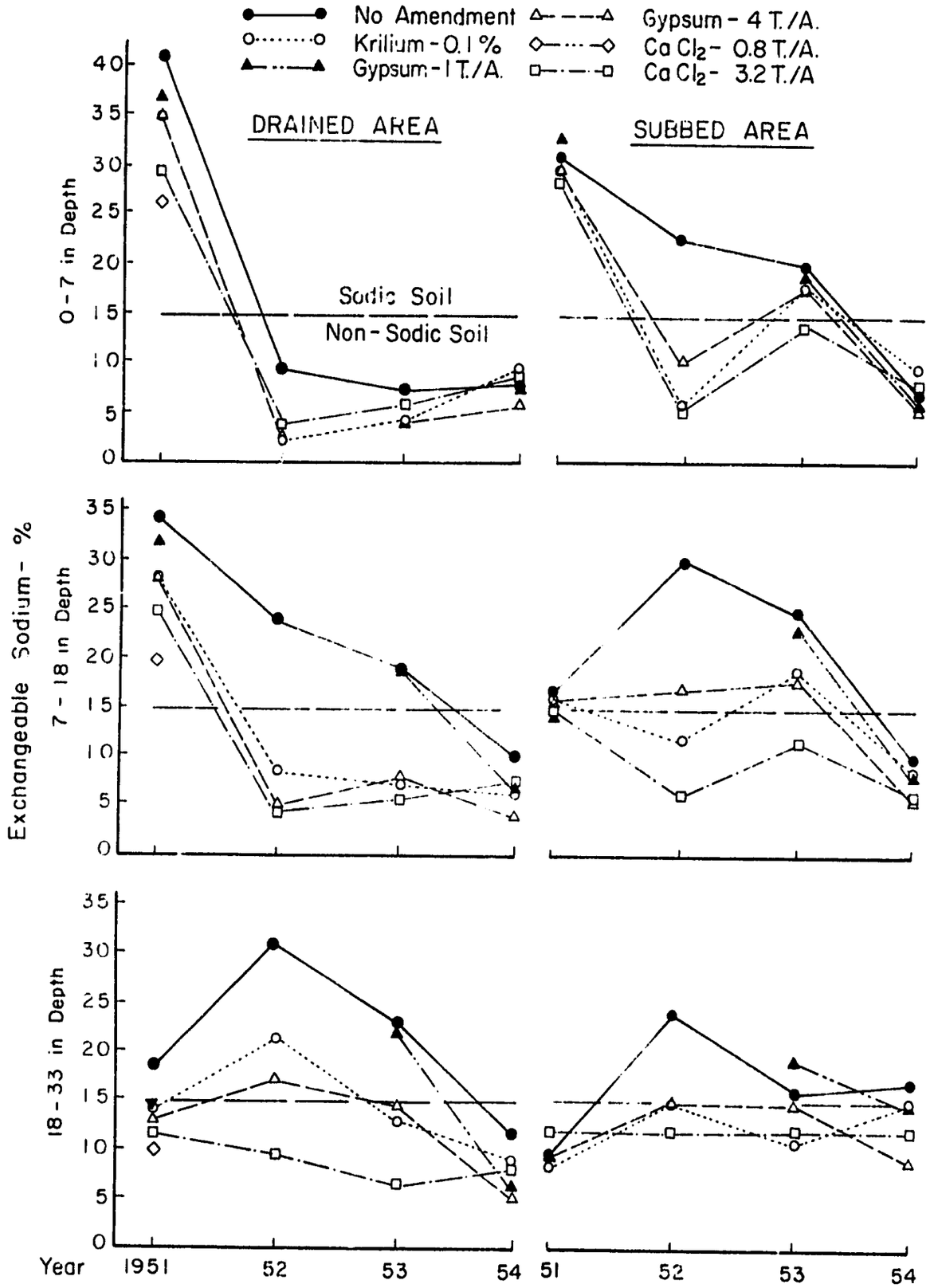


Figure 3. The effects of amendment variables on exchangeable sodium percentages of plots pre-leached with 30 A.-in./A. of water.

Table 2. Exchangeable sodium losses and gains in the 0-33 inch depths of the drained and subbed areas, 1951-1954.

Amendment	Leach	TOTAL EXCHANGEABLE SODIUM IN THE 0-33 INCH DEPTH Drained Area: Initial 1951	Loss(-)2/ 1953	Loss(-)2/ 1954	Loss(-) 1953	Loss(-) 1954	Subbed Area: Initial 1951	Gain(+) or Loss(-) 1953	Gain(+) or Loss(-) 1954	Gain(+) or Loss(-) 1953	Gain(+) or Loss(-) 1954
	A.-in./A.	Lb.-Eq./A.			%		Lb.-Eq./A.			%	
None	12+9*	189	-67	-123	-36	-65	151	+20	-71	+13	-47
	30	251	-92	-150	-37	-60	155	+45	-39	+29	-25
Krilium - 0.1%	12+9	164		-92		-56	149		-32		-32
	30	206	-81 1/	-133	-44 1/	-65	125	+58 1/	-25	+69 1/	-25
1 T./A. Gypsum	12+9	193	-52	-125	-27	-65	156	+25	-70	+16	-45
	30	214	-69	-145	-32	-68	160	+41	-55	+26	-34
4 T./A. Gypsum	12+9	182	-69	-133	-38	-73	146	+29	-92	+20	-63
	30	199	-116	-154	-58	-77	158	+4	-87	+2	-55
0.8 T./A. Calcium Chloride	12+9	158		-72		-46	182		-70		-38
	30	143		-86		-60	129		-47		-37
3.2 T./A. Calcium Chloride	12+9	185		-122		-66	191		-88		-46
	30	177	-155 1/	-120	-76 1/	-68	139	-32 1/	-59	-22 1/	-42
Average		188		-121		-64	153		-61		-40

1/ Analyses of 1 plot only.
2/ Loss or gain compared with the initial amount.
*Additional 9 A.-in./A. added in the spring of 1954.

end of the first cropping season in 1952 with the 30 A.-in./A. initial leaching rate. At the end of the second cropping season the exchangeable sodium was less than 15% through a depth of 33 inches. These high rate amendment applications, especially the calcium chloride, also were effective in reducing the exchangeable sodium levels of the soil surface layers in the subbed area during the first cropping year.

The krilium treatment appeared to reduce the exchangeable sodium almost as rapidly as the gypsum and calcium chloride treatments. However, the rapid reduction was related mainly to the occurrence of natural soil gypsum in the single krilium plot which was analyzed for exchangeable sodium in the drained area in 1952 and 1953. Also, natural soil gypsum probably accounted for most of the reduction which occurred in the krilium plot in the subbed area.

Where no amendment was applied or no natural gypsum occurred, exchangeable sodium removal was dependent mainly on the calcium and magnesium applied in the water and, as shown in Figure 3, the loss was achieved at a much slower rate. At the end of the 1954 season the exchangeable sodium levels of the plots which received no amendment were only slightly higher than those which received amendments.

About 158 pound-equivalents (lb.-eq.) of calcium and magnesium (about 2700 pounds) had been applied to the soil in the drained area in the 10 A.-ft./A. of leaching and irrigation water by 1954 as compared with about 93 lb.-eq. (about 1860 pounds) of calcium supplied by the high rate application of gypsum and calcium chloride. The apparent efficiency of removal of sodium from the 0-33 inch depth of drained area by the

calcium and magnesium in the water ranged from 78-95%. In the subbed area the efficiency of removal, comparatively, was considerably lower, ranging from 18-33%. As an average of all treatments, only about one-half as much exchangeable sodium was removed from the 0-33 inch depth of the subbed plots as was removed in the drained area.

Effects of water table levels on soluble salt and exchangeable sodium levels, 1955-1964

The average soluble salt and exchangeable sodium levels of the plots from 1955-1964 are shown in Figures 4 and 5. The averages include all individual plots sampled each year. After 1954 variability in salt or exchangeable sodium showed no relation with the original leaching or amendment treatments. The variability was more related to water table fluctuations and applied irrigation water. The water table levels by years are shown at the bottoms of Figures 4 and 5 to show the increase or reduction of soluble salts and exchangeable sodium as the water table raised or lowered.

In the drained area the soluble salt levels remained at a level close to the conductivity of the irrigation water with little or no changes occurring in the three depths sampled with water tables averaging 4.6 to 10.0 feet over the 9-year period. The soluble salts reaccumulated rapidly when the water table raised to about a 3-foot level in the subbed area in 1957 and 1958. With water tables averaging 4.2 to 5.7 feet in this area after 1958 the soluble salt levels again approached those in the drained area.

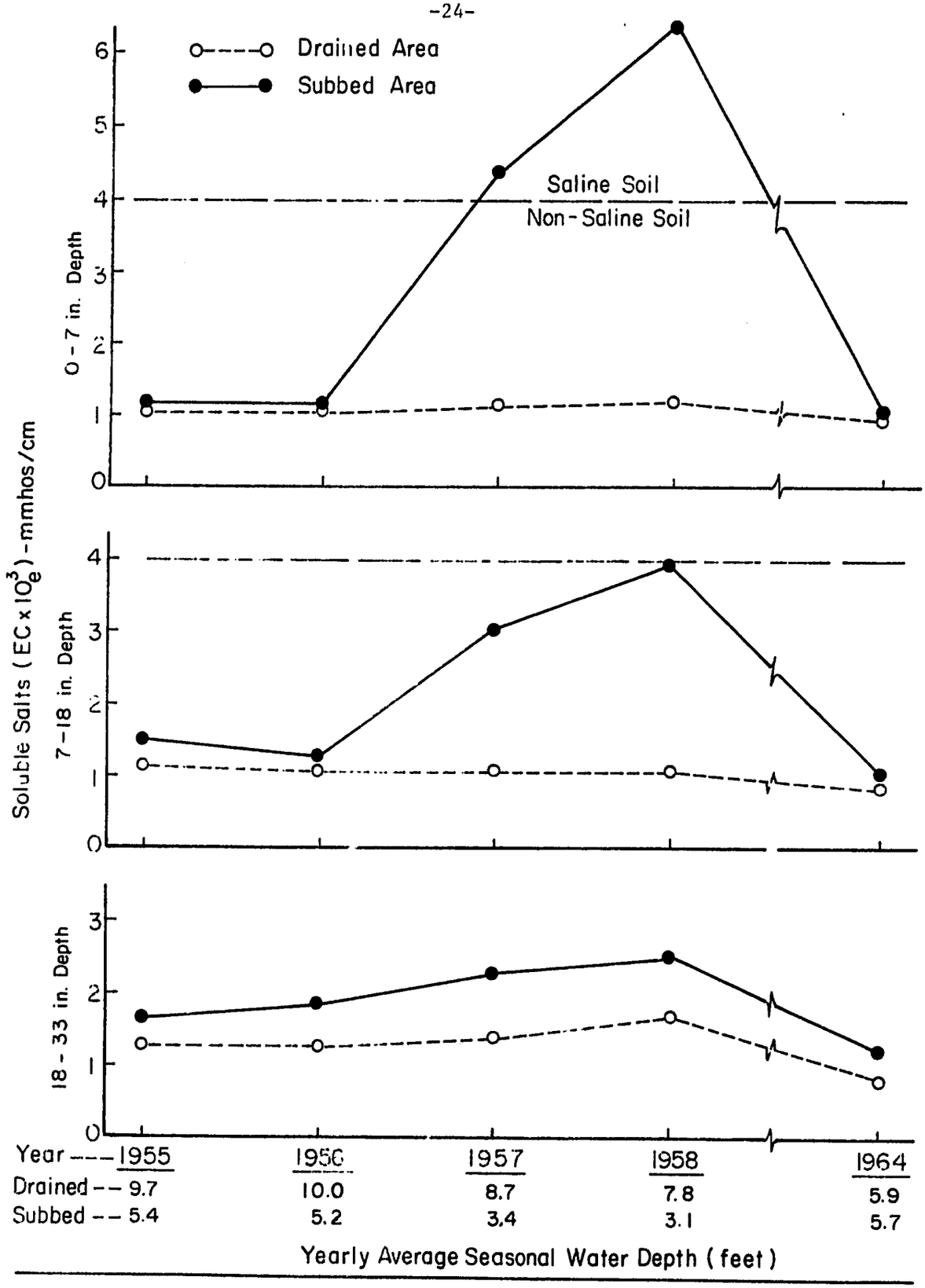


Figure 4. The effects of water table levels on the soluble salt levels of the drained and subbed areas.

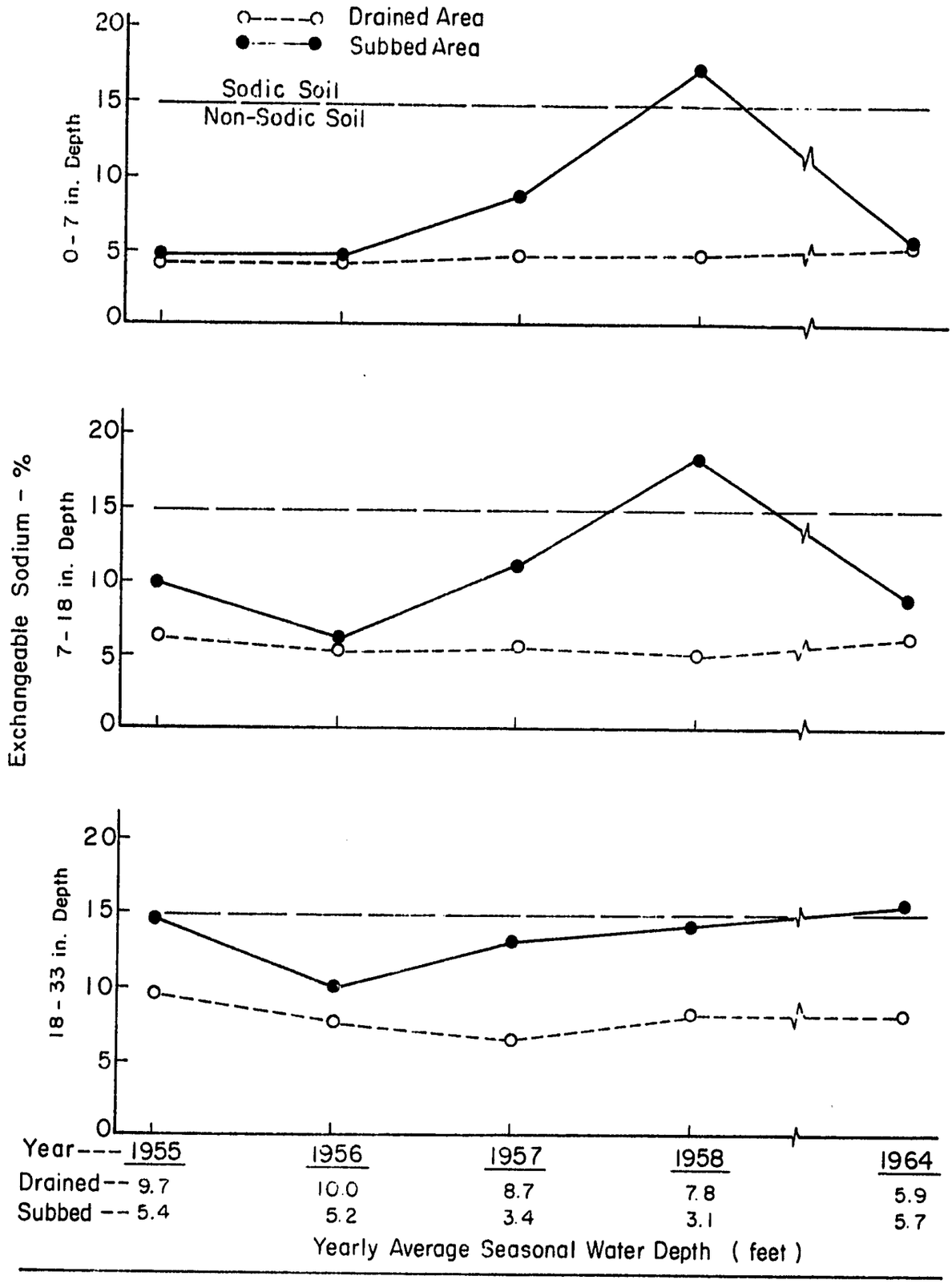


Figure 5. The effects of water table levels on the average exchangeable sodium percentages in the drained and subbed areas.

The exchangeable sodium percentages reached an apparent equilibrium of about 5% in the 0-18 inch depth of the drained area and maintained this level until the experiment was discontinued. The exchangeable sodium, as well as the soluble salts, reaccumulated rapidly in the subbed area when the water table level raised to about 3 feet in 1957 and 1958. With the drop in water table after 1958, the exchangeable sodium decreased in the 0-18 inch depths but it was still undesirably high in the 18-33 inch depth in 1964.

Crop Yields

In the final analysis the effectiveness and practicality of soil reclamation or other treatments must be evaluated in terms of the benefit in increasing crop yields. Also, the economic feasibility of a particular treatment must be considered before it is adopted.

Evaluating the effectiveness of a treatment in terms of crop yields is usually difficult unless the factor for which the treatment was intended to correct is limiting crop production. When dealing with saline-sodic soil reclamation, a complex of limiting factors are involved which may include the effects of salts, the effects of sodium, and the poor soil physical condition which usually accompanies high sodium conditions. Salt and sodium reduction can be measured chemically but the physical condition of the soil as an environment for plant roots is sometimes impossible to measure and at best, is determined only under carefully controlled conditions.

Effects of leaching rates on crop yields

According to Bernstein et al. (1955) passing 12 acre-inches of water through a 1-foot depth of soil will reduce the soluble salt content in the 1-foot depth by about 80%. Thus, the average soluble salt levels in the surface foot-depth of soil was probably less than 4 millimohs/cm. after leaching with either 12 or 30 acre-inches per acre of water. At this level soil salts were unlikely to have been detrimental to the initial crop of barley planted with sweetclover. Any difference in the barley yields could most likely be attributed to the difference in exchangeable sodium removal between the two leaching rates because both barley and sweetclover are very salt tolerant. Not enough soil sample analyses were made in the early reclamation stages to determine these relationships more precisely.

The effects of the 12 and 30-acre-inch leaching rates on the 1952 barley grain yields are shown in Figure 6. The average barley yield in the drained area was higher by 3 bushels per acre where the 30-acre-inch leaching rate was applied, whereas, no increase was obtained in the subbed area. The leaching rates had more effect on the sweetclover stands in the subbed area and subsequent sweetclover hay yields in 1953 (Figure 7). An increased yield of about 0.3 ton per acre was obtained on plots leached with 30-acre-inches. It is not clear whether the yield difference was due to the stand difference or soil factors. No yield difference was obtained in the drained area where the sweetclover stands were more nearly the same.

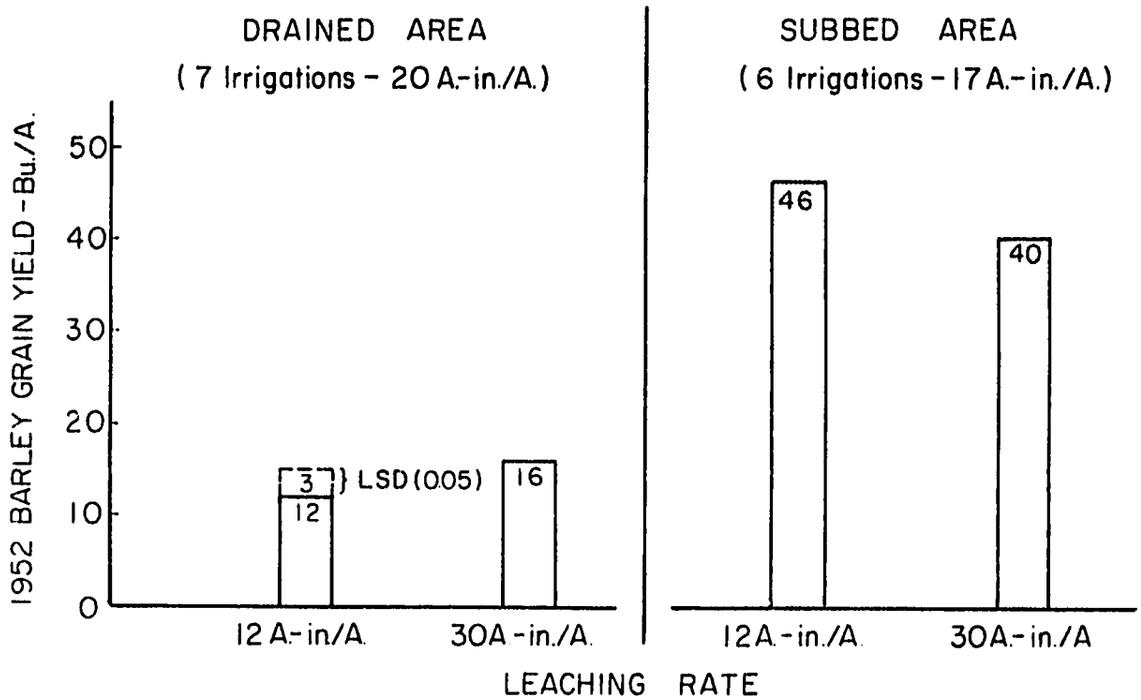


Figure 6. The effect of the initial pre-leaching rates on the 1952 barley grain yields under water table levels averaging 5.7 (Drained) and 2.1 (Subbed) feet.

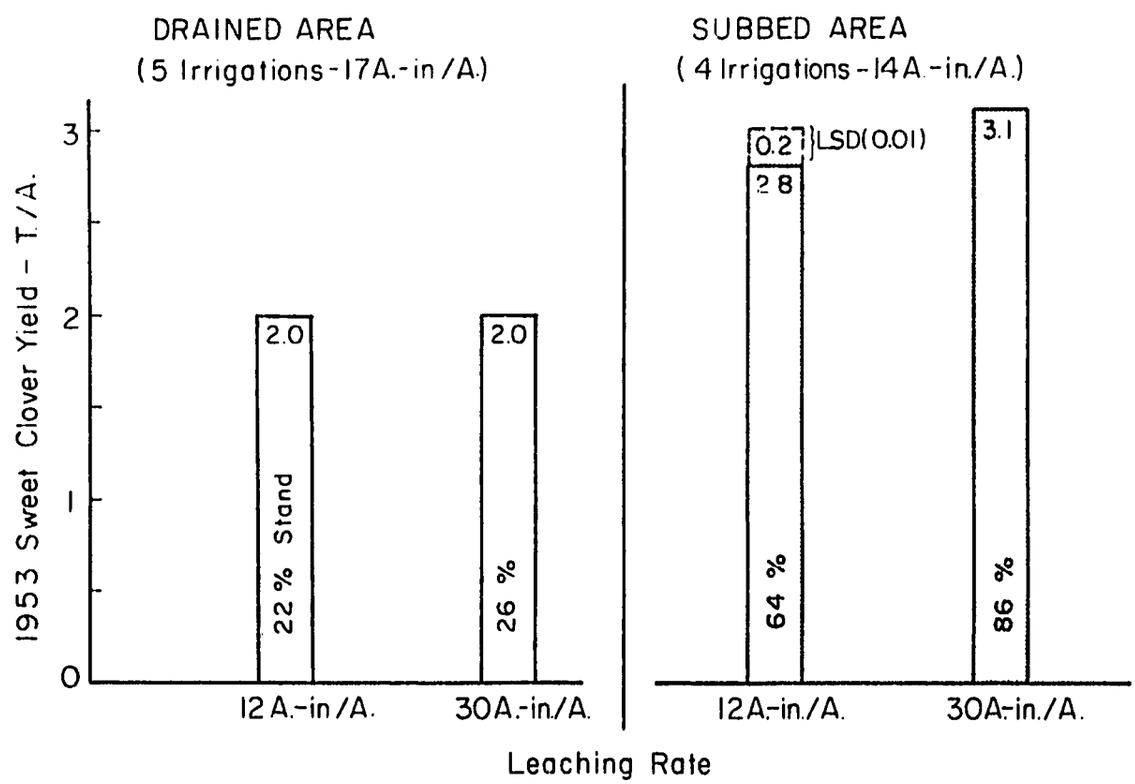


Figure 7. The effects of the initial pre-leaching rates on the 1953 sweetclover hay yields under water table levels averaging 5.4 (Drained) and 2.7 (Subbed) feet.

The effects of the 12 plus 9 acre-inches of leaching water (applied in the spring of 1954) are compared with the 30-acre-inch rate for potatoes grown in 1954 in Figure 8. A statistically significant

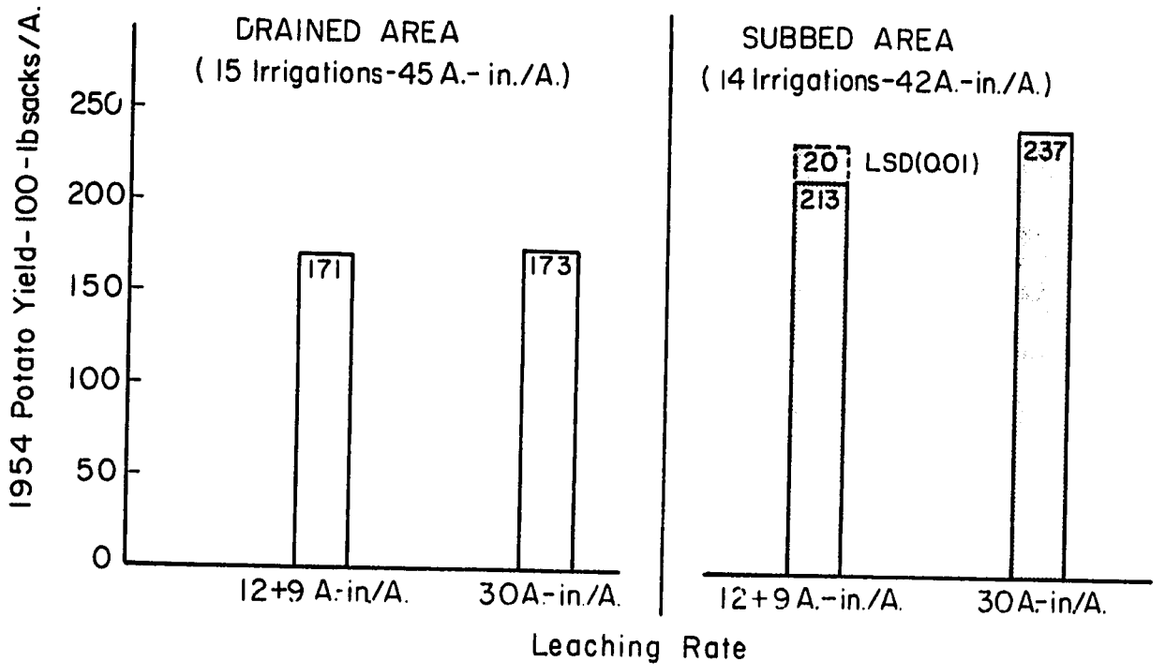


Figure 8. The effect of the initial and additional (1954) leaching rates on the 1954 potato yields under water table levels averaging 8.0 (Drained) and 4.6 (Subbed) feet.

increase of 24 sacks per acre was found for the 30-acre-inch treatment in the subbed area but no significant difference in the drained area. The extra leaching applied early in 1954 had no apparent benefit for the potato crop.

By the end of the 1954 season approximately the same amount of leaching water had been added on the two original leaching treatments and 3-4 times more water was applied for irrigation as for the leaching treatments. Thus, little or no difference in the yields of

subsequent crops after 1954 due to the pre-leaching rates was expected.

Effects of amendments on crop yields

Amendments are applied to furnish a source of soluble calcium to replace excessive adsorbed sodium. The detrimental effects of adsorbed or exchangeable sodium on plant growth are: (1) deterioration of the soil structure which results in a poor medium for plant growth; (2) the possible direct toxicity of the sodium to the plant, and; (3) high soil reactions (pH) which often bring about nutritional imbalances in the plant. As long as excessive salts occur with excessive exchangeable sodium the soil clay remains flocculated and in a favorable physical condition. If the salts are leached out, the soil becomes dispersed and cloddy

The deterioration of the physical condition of saline-sodic soils usually occurs during the leaching process because the salts are removed much faster than the sodium. This was especially true of the highly water permeable coarse-textured soils under investigation. Although the exchangeable sodium was reduced to a non-sodic level, the soil surface became hard and brick-like during the early stages of reclamation if the soil became dry. The soil is low in organic matter, generally less than 0.2% and the clay-type consists mainly of mica (illite). The low organic matter, the non-swelling clay type, plus the high sand content of the soil contribute to rapid packing which apparently resulted in a poor medium for plant growth.

The effects of the amendment applications on the 1952 barley grain yields are shown in Figure 9. Barley grain yields were

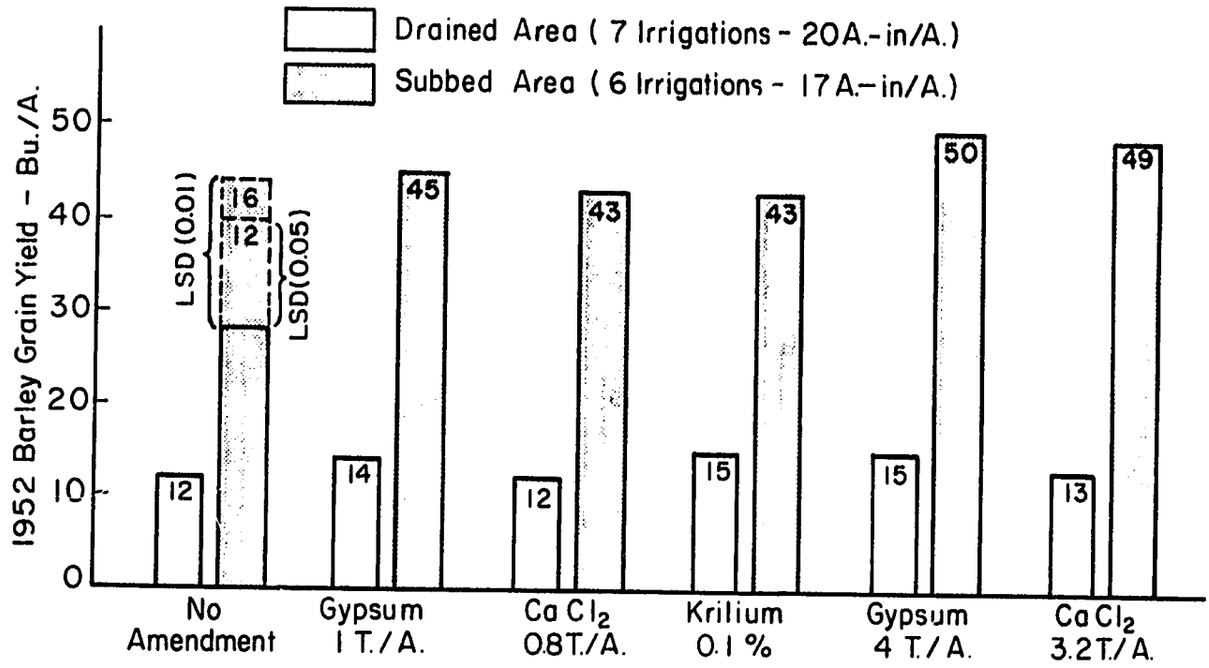


Figure 9. The effect of amendments on barley grain yields under water table levels averaging 5.7 (Drained) and 2.1 (Subbed) feet.

significantly increased by the amendment applications and krilium only under high water table conditions in the subbed area. The higher rate of the amendments did not significantly increase grain yields over the lower rate.

The effects of amendments on the 1953 sweetclover hay yields are shown in Figure 10. The amendments did not produce a significant yield increase in either the drained or subbed area. A trend for a higher yield with the high rate applications of gypsum and calcium chloride in the drained area is indicated. This might be related to the somewhat better sweetclover stands obtained from these treatments.

The amendment effects on the 1954 potato yields are shown in Figure 11. A significant yield increase was again produced by the amendments

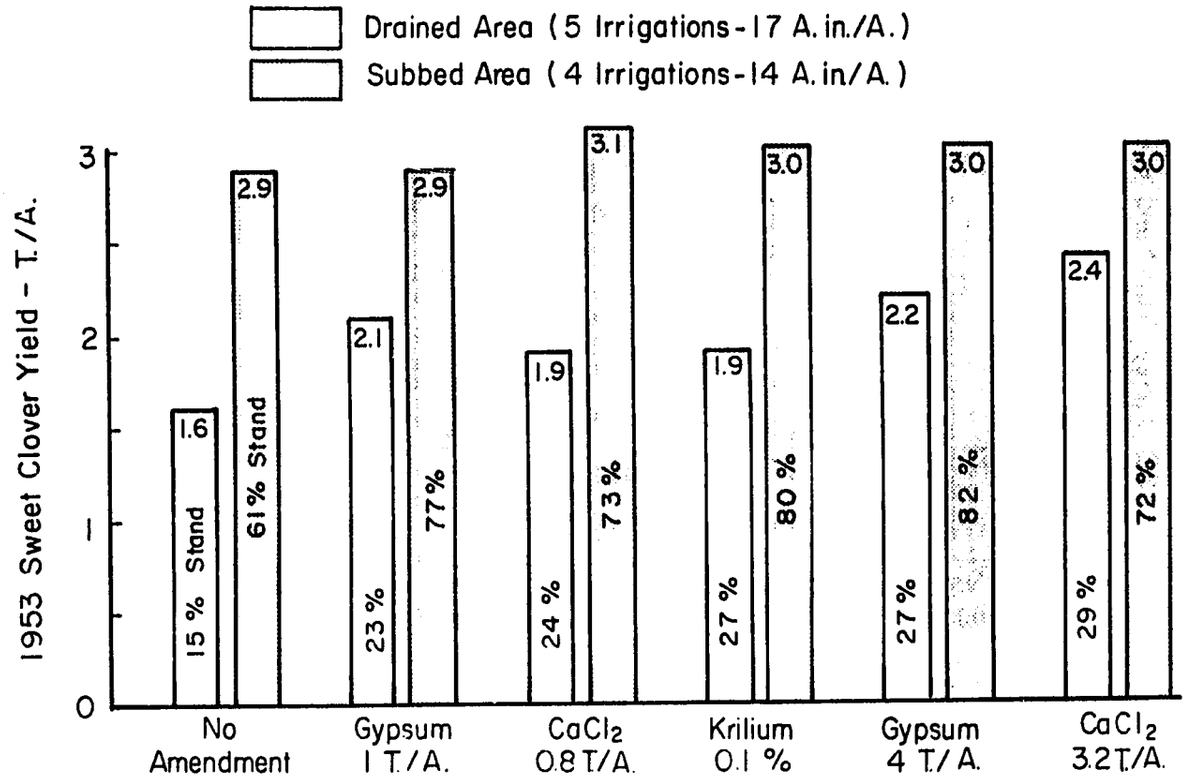


Figure 10. The effects of amendments on sweetclover hay yields under water table levels averaging 5.4 (Drained) and 2.7 (Subbed) feet.

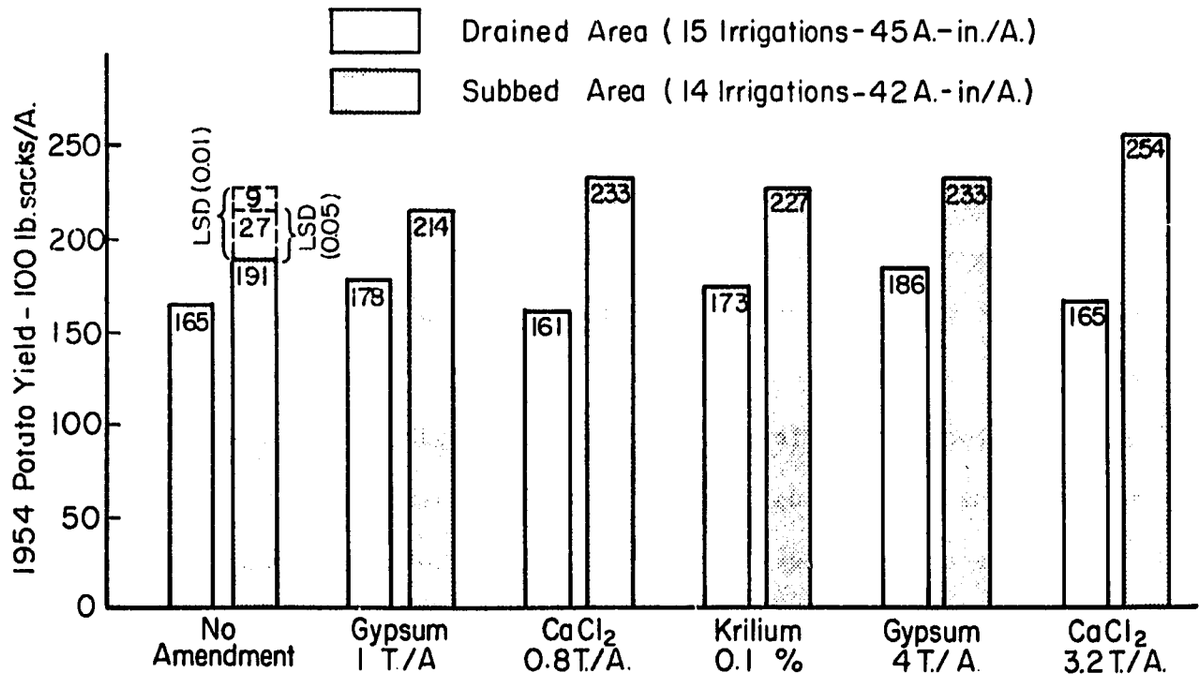


Figure 11. The effect of amendments on the yields of Red McClure potatoes under water table levels averaging 8.0 (Drained) and 4.6 (Subbed) feet.

in the subbed area, except for the 1 ton per acre gypsum rate. The potato yields tended to decrease with increasing exchangeable sodium percentages remaining in the 7-18 inch depth at the end of the 1953 season (Appendix Tables 2a-c). No significant yield increase from the amendments was obtained in the drained area in 1954.

Figure 12 shows the effects of amendments on the 1956 alfalfa hay yields. In both the drained and subbed areas plots on which the high rates of gypsum and calcium chloride and the krilium were applied produced significantly higher yields than on those plots where no amendment or the low rates were applied.

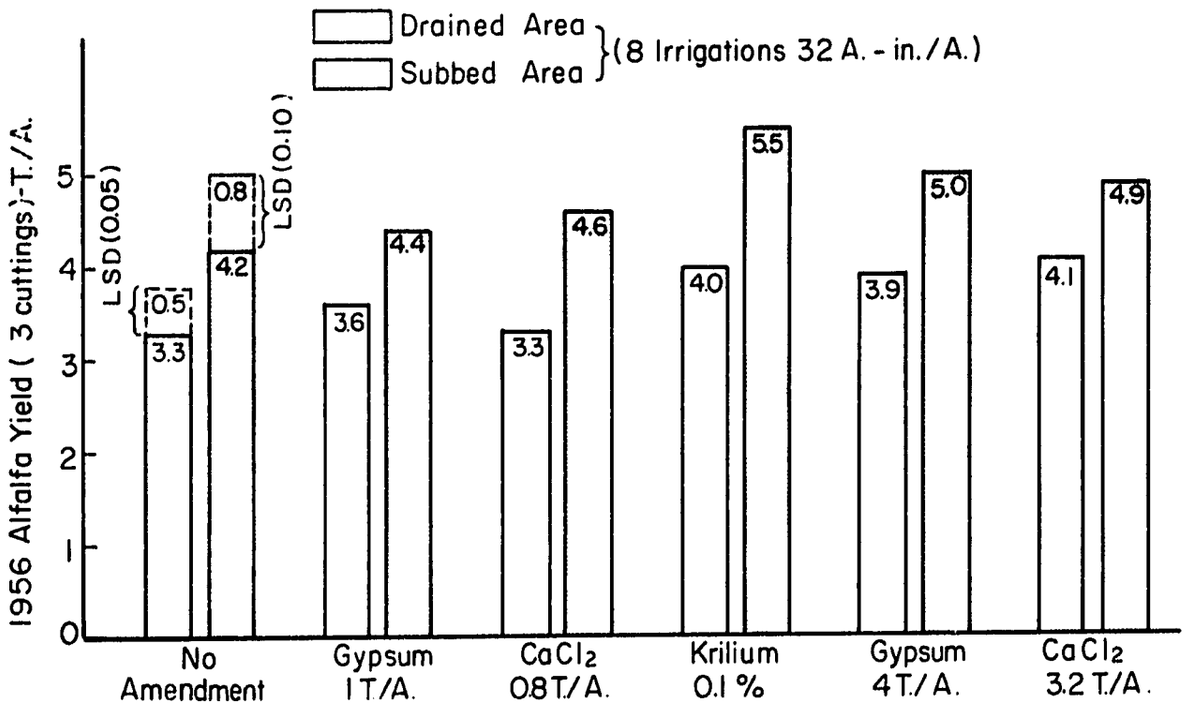


Figure 12. The effects of amendments on the 1956 alfalfa hay yields under water table levels averaging 9.8 (Drained) and 5.2 (Subbed) feet.

The exchangeable sodium and salts were at a low level with little difference between any plots at the end of the 1956 season. Alfalfa usually develops increasing salt and sodium tolerance with age. No difference in alfalfa hay yields between any of the amendment treatments was found during the other years that alfalfa was grown, 1957 through 1960.

A summary of the grain yields obtained on the amendment plots from 1961 through 1963 is shown in Table 3. Although not significant statistically, the application of amendments appears to have some residual effect in increasing grain yields especially in the former "drained" area when the highest water table conditions existed. As the water table dropped from 1962 to 1963 the effect of increased yields from the amendments appears to be decreased somewhat.

Table 3. Summary of average grain yields on plots which received amendments (1952 only) after discontinuing pumping, 1961-1963.

	1961-Barley		1962-Barley		1963-Oats	
Amendment	Drained	Subbed	Drained	Subbed	Drained	Subbed
	Bu./A.		Bu./A.		Bu./A.	
None	44	64	58	75	94	121
Krilium - 0.1%	59	75	78	83	111	121
Gypsum - 1 T./A.	52	71	64	82	98	123
Gypsum - 4 T./A.	55	78	74	78	101	131
$CaCl_2$ - 0.8 T./A.	50	71	65	76	100	130
$CaCl_2$ - 3.2 T./A.	49	76	74	79	105	130
Average Water Table Level-Ft.	4.7	4.5	4.6	4.2	5.5	5.2

Effects of water table levels and irrigation on crop yields

A high water table can have a beneficial effect on crop growth by increasing the available supply of water in the plant root zone especially with coarse-textured soils of low water-holding capacity. Nitrate-nitrogen and possibly other nutrient elements in the groundwater may also produce a beneficial effect on crop growth. Boron in the water and in the soil can have a detrimental effect on crop growth especially if boron is allowed to accumulate in the soil.

The nitrate content of the well water (Appendix Table 4), although a fairly low value of about 6-7 parts per million may have contributed to increased yields under high water table conditions. The boron content of the water was low enough so that there should have been no toxic effects on any of the crops grown.

An unbiased direct comparison of the effects of the water table levels on crop yields is not possible for all years because the crops did not receive the same number of irrigations several of the cropping years and also because of soil texture variation. Further, water table levels were not replicated treatments and it was found that the effects of water tables on crop yields could not be statistically analyzed a majority of the years. After 1955, tensiometers were used as general guides for timing the application of irrigations with the objectives of irrigating as efficiently as possible. In general, a less frequent need for irrigation was indicated by the tensiometers in the subbed area even after pumping was discontinued and the water table levels were approximately the same in each area. The reason for this less

frequent need was apparently due to a generally finer-textured sub-soil with a higher clay and silt content in parts of the subbed area. This finer-textured sub-soil apparently had a greater water holding capacity and a greater capillary conductivity than the generally coarser-textured drained area sub-soil.

Table 4 is a summary of the average crop yields obtained in the two areas under varying water table levels and with varying amounts of irrigation for the 13-year cropping period.

The subbed area produced consistently higher average yields (average of all treatments including irrigations which were not equal in all cases) of the shallower-rooted crops, barley, potatoes and oats, except in 1959, 1960, and 1964. For the most part these higher yields can be attributed directly to maintaining a higher water table level. The yield increase for barley, while the water table difference was maintained, ranged from 30 bushels per acre in 1952 to 6 bushels per acre in 1955. Potato yields (1954) were 78 sacks per acre greater under the higher water table level.

With the deeper-rooted crops sweetclover and alfalfa the water table level was the most important factor in increasing yields while the crop was being established and roots developing. The 1953 average sweetclover hay yield on the subbed area was 1 ton per acre higher than the drained area. However, part of this difference can be attributed to the stand differences obtained in 1952 (Figures 7 and 10). The 1956 average alfalfa hay yield on the subbed area was 1.1 tons per acre greater than on the drained area. Comparing low irrigation rates for

Table 4. Summary of crop yield averages obtained with surface irrigation and irrigation rates in areas varying in water table depths.

		DRAINED AREA						SUBBED AREA					
Year	Crop	Avg. Water Table Level	Amount and No. of Irrigations		Avg. Irrigation Rate Yield		Avg. Area Yield	Avg. Water Table Level	Amount and No. of Irrigations		Avg. Irrigation Rate Yield		Avg. Area Yield
		ft.	Low	High	Low	High		ft.	Low	High	Low	High	
			A.-in./A.						A.-in./A.				
1952	Barley	5.7	20(7)		-		14Bu/A	2.1	17(6)		-		44Bu/A
1953	Sweetclover	5.4	17(4)		-		2.0T/A	2.7	14(4)		-		3.0T/A
1954	Potatoes	8.0	45(15)		-		172 Sacks/A	4.6	42(14)		-		250 Sacks/A
1955	Barley	9.7	24(6)	48(12)	8.2	7.5	8 Bu/A	5.4	20(5)	32(8)	11.0	16.4	14Bu/A
1956	Alfalfa (3 Cuts)	9.8	32(8)		-		3.7T/A	5.2	32(8)		-		4.8T/A
1957	Alfalfa (2 Cuts)	8.7	8(2)	20(5)	3.0	3.8	3.4T/A	3.4	4(1)	12(3)	3.9	3.8	3.8T/A
1958	Alfalfa (3 Cuts)	7.8	12(3)	24(6)	3.8	5.1	4.4T/A	3.1	0	8(2)	5.3	5.2	5.3T/A
1959*	Alfalfa (2 Cuts)	5.0	0	12(3)	3.1	3.4	3.3T/A	4.7	0	12(3)	2.9	3.3	3.1T/A
1960	Alfalfa (2 Cuts)	5.4	12(3)		-		4.1T/A	5.1	12(3)		-		3.8T/A
1961	Barley	4.7	20(5)		-		51Bu/A	4.5	20(5)		-		72Bu/A
1962	Barley	4.6	12(3)	24(6)	65	74	69Bu/A	4.2	8(2)	16(4)	76	80	78Bu/A
1963	Oats	5.5	30(7)		-		102Bu/A	5.2	30(7)		-		126Bu/A
1964	Oats	5.9	16(4)		-		42Bu/A	5.7	12(3)		-		37Bu/A

*Pumping to maintain a water table level difference was discontinued in 1959.

1957 and 1958, the higher water table level increased alfalfa hay yields 0.9 and 1.5 tons per acre.

After the pumping to maintain a water table difference was discontinued in 1959, the trend for higher yields in the subbed area reversed and a slightly higher average alfalfa hay yield was obtained on the drained area. This reversed yield trend may have been due partially to the higher salt and exchangeable sodium content of the subbed area which reaccumulated during the 1957 and 1958 season (Figures 4 and 5). With the water table approximately the same level in 1961, 1962, and 1963 and comparing yields with the same number of irrigations, the subbed area produced higher average yields of 21, 17, and 24 bushels per acre of barley and oats. These yield increases mainly reflect the soil textural differences in the two areas.

The response of the various crops to irrigation and irrigation rates was strongly dependent upon the water table level and the type and the stage of development of root system of the crop. The irrigation rates applied in 1955 had more of an effect on the alfalfa stands and on the subsequent 1956 alfalfa hay yield (Figure 13) than was obtained on the 1955 barley yields. Very little increase in barley grain yields was obtained from increasing irrigations in either area in 1955. A severe June freeze plus later damage by birds largely contributed to the very low yields obtained in both areas. (Also, a June freeze was responsible for reducing the first-cutting alfalfa yields in 1959.)

Three extra irrigations increased alfalfa hay yields 0.8 and 1.5 tons per acre in 1957 and 1958 in the drained area with the average

water table levels at 8.7 and 7.8 feet. Two extra irrigations did not increase hay yields in the subbed area with water table levels averaging 3.4 and 3.1 feet in 1957 and 1958. In 1959 when continuous pumping to produce a water table difference between areas was discontinued, three irrigations increased the alfalfa hay yields by .3 - .4 tons per acre with the water table levels averaging 5.0 and 4.7 feet. Two extra irrigations on the barley grown in 1962 produced only increases of 11 and 4 bushels per acre, respectively in the drained and subbed areas with water table levels at 4.6 and 4.2 feet.

Yield increases due to differences in irrigation rates were not statistically significant for any of the crops even though a large yield difference was found some years. This low number of irrigation treatments and replications partially accounts for this lack of statistical significance.

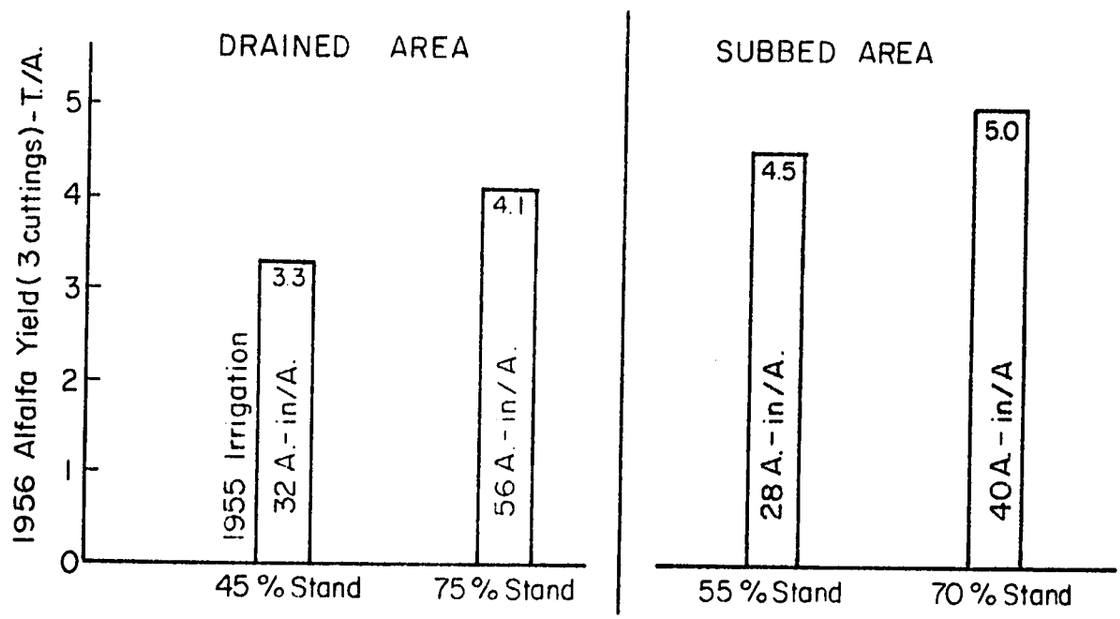


Figure 13. The effect of stand differences produced by the 1955 differential irrigation rate on the 1956 alfalfa hay yields.

The overall importance of the timing and amount of irrigation and water table levels is strongly shown in the oats yield differences between the 1963 and 1964 seasons. Irrigation was restricted in 1964 to simulate irrigation by sporadic river water delivery in the average dry year. Both areas were pre-irrigated before planting. The second irrigation was applied approximately 6 weeks later. The third irrigation was applied approximately a month after the second. The total of 4 irrigations applied on the drained area with water table level of 5.9 feet yielded 42 bushels per acre, a yield reduction of 60 bushels per acre from the 1963 season. Three irrigations only, on the subbed area in 1964 with the water table averaging 5.7 feet resulted in an 89 bushel per acre yield reduction over the previous year.

Effects of fertilizers and fertilizer rates on barley yield

Previous to 1962, phosphorus (P_2O_5) was applied in sufficient amounts so that it would not be a limiting factor in plant growth. Nitrogen (N) was applied on the barley and potatoes at the rate generally recommended for each crop in the area (Appendix Table 6).

A fertility trial was conducted on barley in 1962 to determine the effects of nitrogen and phosphorus fertilizers with different irrigation rates on the reclaimed plots. The irrigation and fertilizer treatments were superimposed over the initial amendment and leaching treatments. The fertilizers and rates of fertilization were applied in strips on each plot. The barley grain yield averages for the fertilizer and irrigation rates are shown in Table 5.

Table 5. The 1962 average Otis barley grain yields for the fertilizer and irrigation rates on the reclaimed plots.

Fertilizer Applications	DRAINED AREA* Barley Yield Irrigation(A.-in./A.) 16	24	Avg.	SUBBED AREA* Barley Yield Irrigation(A.-in./A.) 8	16	Avg.
	Bu./A.			Bu./A.		
0	47	59	53	72	60	66
50 N	69	77	73	73	85	79
100 N	56	87	72	83	91	87
50 N + 50 P_2O_5	71	71	71	71	79	74
100 N + 50 P_2O_5	85	77	81	81	90	86
Average	65	74	69	76	80	78
Fertilizer and Rate LSD .05		8 Bu./A.			12 Bu./A.	
.01		9 Bu./A.		Not significant		
Fertilizer x Irrigation .05		12 Bu./A.		Not significant		
.01		15 Bu./A.		Not significant		

*Continuous pumping to produce water table difference discontinued.

The fertilizer response was not entirely consistent either for rate of application, for irrigation rates, or for the different areas. In general, there were more interactions between fertilizers, residual effects of amendments, and irrigation than was expected. Also, there was considerable border effect from the fertilizer treatments which caused the check or no fertilizer treatment to have higher yields than would be obtained on larger plots. In general, the greatest yield increase per pound of applied N was obtained from the application of 50 pounds per acre of nitrogen. No consistent yield increase was obtained from the application of phosphorus fertilizer. In view of the fact that 650 pounds of phosphate (P_2O_5) had been uniformly applied

on the plots in the years previous to the fertility trial, the general lack of response to phosphorus is highly probable.

The same fertilizers and rates of fertilizer were applied on extra 20 by 20-foot plots in each area which had not been cropped until the previous year to determine the effects of fertilizers on soil with a minimum of reclamation. These plots had been planted with barley in 1961 and received no reclamation treatment other than the irrigation water applied. The yield results on the minimally-reclaimed plots are shown in Table 6.

Table 6. The average 1962 barley grain yields for fertilizers and rates on minimally-reclaimed plots.

Fertilizer Applications	DRAINED AREA Barley Yield	SUBBED AREA Barley Yield
Lbs./A.	Bu./A	Bu./A.
0	24	27
50 N	16	45
100 N	22	35
50 N + 50 P_2O_5	23	22
100 N + 50 P_2O_5	18	49
Average	20	36
Fertilizer and rate LSD .05	Not significant	18 Bu./A.

There was no yield increase due to fertilizers or fertilizer rates in the drained area. The soil surfaces of the plots in this area were uniformly hard and brick-like on the surface due to the high exchangeable

sodium content. The subbed area gave a more spotty appearance. A significant yield increase over the 0 fertilizer treatment was obtained for the 50 pounds of nitrogen and 100 pounds of nitrogen plus 50 pounds of phosphate.

The data indicate that little yield increase can be expected where high exchangeable sodium and poor soil physical conditions exist. Where the exchangeable sodium conditions are "spotty", variable responses to fertilizer can be expected.

Effects of subsoil tillage on oat yields

The average oat yields for subsoil-tilled and non-tilled areas are shown in Table 7.

Table 7. Average 1963 and 1964 Parker grain yields for chiseled and non-chiseled treatments.

Tillage Treatment	DRAINED AREA* OAT YIELD Year 1963	1964	SUBBED AREA* OAT YIELD Year 1963	1964
	Bu./A.		Bu./A.	
Not chiseled	98	42.4	129	39.2
30-In. Chisel	105	41.1	124	34.7
Tillage LSD .05	Not Significant	Not Significant	Not Significant	3.9 Bu./A.

*Continuous pumping to produce water table difference discontinued.

The 30-inch deep chiseling treatment produced an average (including all original amendment and leaching treatments) increase of 7 bushels per acre in the drained area in 1963. A larger yield increase

(21 Bu./A.) was found on the original no amendment and krilium treated plots. Smaller or no yield increases from chiseling was found for plots originally treated with calcium chloride and gypsum (Appendix Table 18) which resulted in the relatively low overall average for 1963 In 1964 a slight yield decrease was found in the drained area.

A consistent yield decrease on the chiseled plots was found in the subbed area in both 1963 and 1964. A decrease in the water-holding capacity of the loosened soil probably best explains the decreased yield in the subbed area.

In general, the data indicate that subsoil tillage is of limited value when applied on well-reclaimed coarse-textured soils and in some cases, may even be detrimental to crop growth.

DISCUSSION

Need for Reclamation and Feasibility

Cropping even with the most salt and sodium tolerant crops will be extremely hazardous, if not impossible in some spots, if some reclamation treatments are not applied on the saline-sodic loamy sand soils similar to those at the experimental site. The excessive soluble salts and the relatively low total amounts of exchangeable sodium present mainly in the surface 18 inches of soil make it possible to reduce soluble salts and exchangeable sodium in the crop root zone to desirably low levels in one season using amendments and with the water table at a 4½ - 5 foot depth. Reclamation can be accomplished with high calcium-magnesium groundwater alone but it requires a longer period of time.

The primary prerequisite for reclamation treatments and cropping of the soil is a readily available and dependable supply of water throughout the cropping season. More than one source of water might be utilized for this purpose. Some farms have river water rights, some farmers have installed shallow-groundwater wells with reservoirs, and others have developed deeper artesian wells. Each of these sources has advantages and disadvantages for the purpose of reclaiming the soils. The river water supply does not last throughout the growing season most years. Both the river water and the artesian water, in general, contain low total calcium and magnesium which makes it necessary to apply greater amounts of amendments to remove exchangeable sodium from the soil. The shallow groundwater offers some advantage in this respect but the calcium and magnesium content may vary considerably from place to place within the area.

The shallow-groundwater well can serve as a water table control measure when the water table is high but it may lower the water table excessively during low water table periods. The advantage of lower drilling costs of the shallow wells over the deeper artesian wells may be substantially offset by the cost of the pumping plant and annual pumping costs.

Water Table Control Requirements for Reclamation

The experimental results indicate that the water table should be at a level not higher than 4 feet in order to obtain salt and sodium removal from the top 3 feet of soils. More rapid salt and sodium removal results when the level is lower than 4 feet.

The need for water table control using open drain ditches or other water table control measures appears to have considerable variability in the Mosca-Hooper area and the San Luis Valley in general. At the experimental site the water table fluctuated from season-to-season and considerably from year-to-year. The highest water table level recorded in the vicinity outside the plot areas during the period 1952-1964 was 3.0 feet in the spring of 1953. The lowest level recorded during this time was 6.7 feet during the fall of 1956 (Appendix Table 3). The highest water tables coincided with years when favorable snow packs occurred and more-than-usual river water supplies were diverted into the area. In a somewhat isolated situation where little land was irrigated in the immediate vicinity such as the land at the experimental site, drains would not be necessary to accomplish reclamation. Reclamation could be accomplished during periodswhen low water tables occurred.

In other situations, especially with land adjacent to canals or where considerable irrigation with water other than groundwater was taking place in the vicinity, drainage would usually be necessary to accomplish reclamation. In the isolated situation installing drains would apt to be prohibitive on an individual basis because of the cost involved and because of the difficulty of disposing of the excess water. Cooperation of neighboring land owners would be required to install drains in any case.

A major advantage of drainage is that salts which are leached from the soil in the leaching water are removed from the area in the

drainage water. This advantage is reflected in the experimental results. The drained area plots showed little or no tendency to reaccumulate salt or exchangeable sodium.

Water Table Levels for Crop Growth and Salinity Control

In general, in the closed basin area of the San Luis Valley the best crop yields are obtained with no or a minimum of surface irrigation under sub-irrigated conditions where salts and sodium are not a great problem. Water table levels necessary for sub irrigation vary somewhat with the texture of the subsoil. A water table level of 18 inches may be necessary to supply the moisture needs of shallow-rooted crops, such as potatoes or barley, in soils with very gravelly subsoils. In areas with finer-textured subsoils, the water table necessary to sub-irrigate the same crops may be 2 feet or lower.

Maintaining a high water table tends to minimize the effects of high salt and sodium concentrations when they do occur in the coarse-textured soils, especially with the more salt and sodium tolerant crops. This is largely academic in the Mosca-Hooper area, however, because the great fluctuation in water supplies creates fluctuations in the water table levels, most of which are usually below depths necessary to grow crops by sub-irrigation alone. The rapid accumulation of salt and sodium when the water table is 3 feet or higher makes sub-irrigation, as such, a highly questionable practice in the area. During periods when the water table is low the yields of even the more salt and sodium tolerant crops decline to low uneconomical levels especially on sodic soils.

More pertinent questions are whether crop yields can be improved and a high level of crop production maintained by increasing irrigation supplies and applying reclamation treatments at water table levels low enough for soluble salt and exchangeable sodium removal and control.

The results indicate that salt and sodium are reduced in the top 3 feet of the soil and reaccumulation is minimized at a water table level of about 3.5 to 4 feet.

The cropping results indicate that during the early stages of reclamation the yields of shallow-rooted crops, namely barley and potatoes, are undesirably low at water tables ranging from 4½ - 6 feet even though the soluble salt and exchangeable sodium contents of the soil root zone have been substantially reduced. Also, difficulty is experienced in obtaining good stands of sweetclover and alfalfa at these water table levels.

These low yields are thought to be partly due to the compactness and generally poor physical condition of the soil surface. Deterioration of the structure evidently has taken place either before reclamation treatments or occurred during the leaching treatments. The fact that plots treated with krilium, a soil conditioner for improving structure, produced yields as great or greater than yields from plots treated with amendments tends to substantiate the observations on the soil physical condition.

It is apparent that further measures are necessary to improve the soil physical condition in addition to salt and sodium removal before higher yields can be obtained in the early reclamation stage with water

tables of 4 feet or lower. Subsoil tillage to loosen the dispersed and compacted soils before reclamation treatments are applied and an early incorporation of alfalfa into the crop rotation will bring about better yields in the early reclamation stage. (The results of further experiments with subsoil tillage and reclamation are given in a later bulletin.) Chiseling the soil 10 years after reclamation was started did not increase oat yields substantially.

The results show that 2 cuttings of alfalfa will produce about 4 tons per acre of hay with 1 to 2 surface irrigations per cutting at water table levels of 4 to 5 feet after the roots have had time to develop. Reasonably, satisfactory yields of shallow-rooted crops at water table levels lower than 4 feet were not obtained until the salt and sodium was removed from the root zone and alfalfa incorporated into the rotation. The alfalfa apparently brought about some improvement in the soil physical condition. Approximately 70-85 bushels per acre of barley were produced at water table levels of 4-5 feet with 4 to 6 irrigations (about 2 acre-feet of water) and with 50 pounds per acre of nitrogen fertilizer. Approximately 100-125 bushels per acre of oats were produced with 7 irrigations and 70 pounds per acre of nitrogen and 40 pounds per acre of phosphate (P_2O_5) at water table levels averaging 5 feet or below. Reducing the number of irrigations drastically reduced oat yields at water table levels averaging close to 6 feet the year following.

Thus, the results indicate that satisfactory yields can be achieved at water table levels below those necessary for salinity

control if the soil is reclaimed and its physical condition improved, adequate fertilizer is applied, and timely and adequate irrigation is applied. However, the economic feasibility of providing sufficient irrigation water to achieve good yields at water table levels below 5 feet is somewhat questionable.

Water Table Levels for Surface Irrigation

The water table levels necessary for the most rapid removal of soluble salts and exchangeable sodium from the crop root zone of the soils in the area are not the levels at which the most efficient surface irrigation can be attained by flood irrigation. Increasingly larger heads of water or shorter irrigation runs are necessary to cover the land by flood irrigation as the water table level lowers, especially below 4 feet. The fluctuation of the water table also creates problems in irrigation management. Frequent changes in either the size of the irrigation water head or the size of the irrigation run would be necessary to achieve the most efficient irrigation under conditions of water table fluctuation.

The use of sprinkler irrigation would alleviate some of the management problems associated with flood irrigation. However, the capacity of the sprinkler system would have to be large and would increase irrigation costs considerably.

Management of Reclaimed Coarse-Textured Soils

Water management is the key factor in obtaining economically justifiable crop yields on these soils. Water management includes both water table level control and surface irrigation.

Ideally, stabilization of the water table level at about 4 feet with adequate surface irrigation water available from March through October would considerably simplify management in all respects. At this water table level, reclamation could be accomplished and salt accumulation in the root zone eliminated or minimized. Stabilization of the water table would allow more precise and predictable water and fertilizer requirement determinations to be made for various crops.

Water table fluctuation creates considerable uncertainty at all levels of management. Soluble salts, exchangeable sodium, and crop water and fertilizer utilization all have some interactive effect with most crops.

A lowering of the water table generally increases the need for more frequent irrigation which may cause leaching of nitrogen from the root zone, or may decrease the utilization of plant nutrients especially if exchangeable sodium is high in root zone. A rising water table generally decreases the need for surface irrigation during the cropping season, which will decrease nitrogen losses, but may result in excessive salt and sodium accumulations. Also, a rising water table may cause the loss of stands of alfalfa. Soluble salt accumulations in the root zone from a water table rising above 4 feet may not be serious if the water table drops again and pre-season or post-season leaching water is applied to reduce the salts. Removing accumulated exchangeable sodium would require the application of amendments if a low calcium-magnesium water source was used for irrigation. Frequent amendment applications would add to the cost of producing crops and may result in uneconomical production in many cases.

REFERENCES

1. Bernstein, L., M. Fireman, and R. C. Reeve. 1955. Control of salinity in the Imperial Valley of California. U.S.D.A. Agricultural Research Service Bul. 41-4.

2. Cochran, W. G. and G. M. Cox. 1953. Experimental Designs. Chap. 14. Analysis of the results of a series of experiments. John Wiley and Sons, Inc. New York.

3. Powell, W. J. 1958. Ground-water resources of the San Luis Valley, Colorado. Ground Water Series Bulletin No. 3, U. S. Government Printing Office, Washington, D. C.

4. Richards, L. A. 1954 (ed.). Diagnosis and Improvement of Saline and Alkali Soils. U.S.D.A. Handbook No. 60. U. S. Government Printing Office, Washington, D. C.

APPENDIX

Table 1a. The electrical conductivities of saturated soil paste extracts (mmhos/cm.) of the samples from the drained plots pre-leached with 30 A.-in./A. of water.

Amendment	Sampling Date and Number of Plots Sampled								
	Aug.[4/] 1951	Sept.[1/] 1952	Aug.[4/] 1953	Sept.[4/] 1954	Oct.[2/] 1955	Nov.[2/] 1956	Oct.[2/] 1957	Oct.[2/] 1958	Oct.[2/] 1964
				0-7 In. Depth					
None	18.7	1.25	1.01	5.31	1.07	0.88	1.10	1.08	1.0
Krilium - 0.1%	18.0	1.38	1.17[1/]	4.07	1.07	1.19	1.16	1.26	0.9
Gypsum - 1 T./A.	18.6	-	0.97	4.06	-	1.04	1.03	1.16	1.0
Gypsum - 4 T./A.	18.6	3.09	2.03	4.47	1.12	1.31	1.13	1.26	0.8
Calcium Chloride - 0.8 T./A.	12.9	-	-	3.50	-	0.96	1.11	1.16	0.9
Calcium Chloride - 3.2 T./A.	15.6	2.41	0.89[1/]	3.94	0.98	1.08	1.33	1.16	0.9
				7-18 In. Depth					
None	6.69	1.46	2.06	3.42	1.23	1.16	1.13	1.06	0.8
Krilium - 0.1%	7.81	1.67	2.91[1/]	2.69	1.12	1.17	1.00	1.18	0.8
Gypsum - 1 T./A.	5.54	-	2.98	3.12	-	1.22	0.99	1.02	0.7
Gypsum - 4 T./A.	6.24	2.23	3.97	2.58	1.12	1.27	1.03	1.25	0.8
Calcium Chloride - 0.8 T./A.	3.41	-	-	1.78	-	0.72	1.14	1.07	0.8
Calcium Chloride - 3.2 T./A.	5.39	1.08	2.40[1/]	2.35	1.00	0.97	1.10	0.97	0.8
				18-33 In. Depth					
None	2.75	1.73	2.46	1.76	1.57	1.36	1.45	1.48	0.8
Krilium - 0.1%	2.38	2.06	3.01[1/]	1.48	1.22	1.31	2.12	1.26	0.8
Gypsum - 1 T./A.	2.57	-	3.14	1.58	-	1.31	1.14	1.91	0.8
Gypsum - 4 T./A.	2.47	2.59	2.60	1.74	1.12	1.21	1.28	2.86	0.8
Calcium Chloride - 0.8 T./A.	1.61	-	-	1.18	-	0.81	1.20	1.25	0.8
Calcium Chloride - 3.2 T./A.	2.51	1.28	1.51[1/]	1.47	1.23	1.23	1.27	1.12	0.9

1/ Electrical conductivity value of soil sample from 1 plot.
2/ Average electrical conductivity values of soil samples from 2 replicate plots.
4/ Average electrical conductivity values of soil samples from 4 replicate plots.

Table 1b. The electrical conductivities of saturated soil paste extracts (mmhos/cm.) of the samples from the subbed plots pre-leached with 30 A.-in./A. of water.

Amendment	Sampling Date and Number of Plots Sampled								
	Aug. 4/ 1951	Sept. 1/ 1952	Aug. 4/ 1953	Sept. 4/ 1954	Oct. 2/ 1955	Nov. 2/ 1956	Oct. 2/ 1957	Oct. 2/ 1958	Oct. 2/ 1964
				0-7 In. Depth					
None	18.4	2.27	7.76	4.98	1.20	1.07	4.46	6.39	1.0
Krilium - 0.1%	14.7	2.29	9.80 1/	4.41	1.15	1.28	4.51	6.63	1.0
Gypsum - 1 T./A.	17.0	-	8.96	4.67	-	1.37	2.71	6.27	1.1
Gypsum - 4 T./A.	19.4	4.73	9.86	5.08	1.10	1.12	4.70	7.63	0.9
Calcium Chloride - 0.8 T./A.	17.9	-	-	3.48	-	1.22	5.89	6.32	1.1
Calcium Chloride - 3.2 T./A.	17.5	3.57	9.30 1/	4.96	1.30	1.20	5.04	4.84	1.1
				7-18 In. Depth					
None	4.34	2.70	4.14	4.15	1.55	1.30	2.30	2.90	0.9
Krilium - 0.1%	3.38	2.64	3.34 1/	3.71	1.43	1.27	2.39	3.94	1.0
Gypsum - 1 T./A.	4.49	-	5.27	4.55	-	1.26	2.22	4.00	1.2
Gypsum - 4 T./A.	6.04	4.45	5.05	5.02	1.45	1.31	4.01	5.28	1.0
Calcium Chloride - 0.8 T./A.	4.03	-	-	2.59	-	1.55	3.87	4.05	1.1
Calcium Chloride - 3.2 T./A.	4.65	2.93	3.93 1/	4.27	1.55	1.37	3.46	3.10	1.0
				18-33 In. Depth					
None	2.65	2.77	1.80	1.96	1.67	2.70	2.46	2.19	1.1
Krilium - 0.1%	1.84	3.24	2.11 1/	1.67	1.61	1.67	1.82	2.13	1.0
Gypsum - 1 T./A.	2.17	-	2.05	2.05	-	2.01	3.06	2.12	1.4
Gypsum - 4 T./A.	3.59	3.85	1.93	2.35	1.57	1.47	2.02	2.76	1.3
Calcium Chloride - 0.8 T./A.	2.31	-	-	1.52	-	2.16	2.15	3.91	1.2
Calcium Chloride - 3.2 T./A.	2.50	3.36	1.83 1/	1.86	1.71	1.73	2.11	1.80	1.2

1/ Electrical conductivity value of soil sample from 1 plot.
2/ Average electrical conductivity values of soil samples from 2 replicate plots.
4/ Average electrical conductivity values of soil samples from 4 replicate plots.

Table 1c. The electrical conductivities of saturated soil paste extracts (mmhos/cm.) of the samples from the drained and subbed plots pre-leached with 12 A.-in./A. of water.

Amendment	Sampling Date and Number of Plots Sampled									
	DRAINED AREA					SUBBED AREA				
	Aug. 4/ 1951	Aug. 4/ 1953	Sept. 4/ 1954	Nov. 1/ 1956	Oct. 1/ 1957	Aug. 4/ 1951	Aug. 4/ 1953	Sept. 4/ 1954	Nov. 1/ 1956	Oct. 1/ 1957
					0-7 In. Depth					
None	14.9	0.89	4.95	-	-	15.4	5.97	3.98	-	-
Krilium - 0.1%	16.2	-	2.78	-	-	20.5	-	3.49	-	-
Gypsum - 1 T./A.	16.5	1.02	4.95	0.93	1.05	16.7	10.05	3.72	0.92	3.26
Gypsum - 4 T./A.	17.1	1.34	4.38	-	-	18.1	10.90	4.15	-	-
Calcium Chloride - 0.8 T./A.	15.0	-	4.17	1.07	1.03	20.4	-	3.93	0.99	4.02
Calcium Chloride - 3.2 T./A.	16.7	-	4.44	-	-	21.5	-	4.10	-	-
					7-18 In. Depth					
None	6.12	1.76	3.13	-	-	3.74	4.48	3.07	-	-
Krilium - 0.1%	6.04	-	1.95	-	-	4.21	-	2.53	-	-
Gypsum - 1 T./A.	6.39	2.24	2.97	1.10	1.10	4.85	6.31	3.07	0.96	2.71
Gypsum - 4 T./A.	6.24	3.13	2.54	-	-	5.65	7.51	4.14	-	-
Calcium Chloride - 0.8 T./A.	4.96	-	2.43	1.01	1.14	5.20	-	3.93	1.14	3.12
Calcium Chloride - 3.2 T./A.	4.89	-	2.38	-	-	6.59	-	3.93	-	-
					18-33 In. Depth					
None	2.34	2.07	1.63	-	-	2.18	1.76	1.57	-	-
Krilium - 0.1%	2.21	-	1.29	-	-	2.11	-	1.53	-	-
Gypsum - 1 T./A.	2.29	2.84	1.71	1.42	1.20	2.69	2.19	1.65	1.24	2.17
Gypsum - 4 T./A.	2.34	2.62	1.72	-	-	2.67	2.74	2.29	-	-
Calcium Chloride - 0.8 T./A.	2.02	-	1.37	1.19	1.10	3.15	-	1.60	1.93	2.36
Calcium Chloride - 3.2 T./A.	2.36	-	1.31	-	-	2.67	-	2.22	-	-

1/ Electrical conductivity value of soil sample from 1 plot.
4/ Average electrical conductivity values of soil samples from 4 replicate plots.

Table 1d. Summary of electrical conductivity values and statistical analysis before reclamation in 1951 and after complete resampling in 1954.

	1951							
	DRAINED PLOTS Depth-Inches				SUBBED PLOTS Depth-Inches			
Amendments	0-7	7-18	18-33	Avg.	0-7	7-18	18-33	Avg.
No Amendment	16.9	6.4	2.5	8.6	16.9	4.0	2.4	7.8
Krilium	17.1	6.9	2.3	8.8	17.6	3.8	2.0	7.8
Gypsum - 1 T./A.	17.6	6.0	2.4	8.7	16.8	4.7	2.4	8.0
Gypsum - 4 T./A.	17.8	6.2	2.4	8.8	18.8	5.8	3.1	9.2
$CaCl_2$ - 0.8 T./A.	13.9	4.2	1.8	6.6	19.1	4.6	2.7	8.8
$CaCl_2$ - 3.2 T./A.	16.2	5.1	2.4	7.9	19.5	5.6	2.6	9.2
Average	16.6	5.8	2.3	8.2	18.1	4.8	2.5	8.5
Leach				Avg.				Avg.
12 A.-in./A.	16.1	5.8	2.3	8.0	21.0	5.0	2.6	8.8
30 A.-in./A.	17.1	5.9	2.4	8.4	17.5	4.5	2.5	8.2
Coefficient of Variation			25.3%				19.0%	
Amendment LSD .05		1.2 mmhos/cm.				1.2 mmhos/cm.		
.01		1.6 mmhos/cm.				.9 mmhos/cm.		
Depth LSD .05		0.8 mmhos/cm.				0.8 mmhos/cm.		
.01		1.1 mmhos/cm				1.2 mmhos/cm.		

	1954							
	DRAINED PLOTS Depth-Inches				SUBBED PLOTS Depth-Inches			
Amendments	0-7	7-18	18-33	Avg.	0-7	7-18	18-33	Avg.
No Amendment	5.13	3.28	1.69	3.37	4.48	3.61	1.76	3.28
Krilium	3.43	2.32	1.38	2.38	3.95	3.12	1.60	2.89
Gypsum - 1 T./A.	4.80	3.04	1.65	3.16	4.20	3.81	1.85	3.28
Gypsum - 4 T./A.	4.42	2.56	1.73	2.90	4.61	4.58	2.32	3.84
$CaCl_2$ - 0.8 T./A.	3.83	2.10	1.27	2.40	3.71	3.26	1.56	2.84
$CaCl_2$ - 3.2 T./A.	4.19	2.36	1.39	2.65	4.53	4.10	2.04	3.56
Average	4.30	2.61	1.52	2.81	4.25	3.74	1.86	3.28
Leach				Avg.				Avg.
21 A.-in./A.	4.28	2.57	1.51	2.78	3.90	3.45	1.81	3.05
30 A.-in./A.	4.33	2.66	1.54	2.84	4.60	4.05	1.90	3.52
Coefficient of Variation			25.1%				31.7%	
Amendment LSD .05		0.40 mmhos/cm.				0.60 mmhos/cm.		
.01		0.53 mmhos/cm.				0.79 mmhos/cm.		
Leach LSD .05		Not Significant				0.34 mmhos/cm.		
.01		Not Significant				0.46 mmhos/cm.		
Depth LSD .05		0.29 mmhos/cm.				0.42 mmhos/cm.		
.01		0.38 mmhos/cm.				0.56 mmhos/cm.		

Table 2a. Exchangeable sodium percentages of the soil samples from the drained plots pre-leached with 30 A.-in./A. of water.

Amendment	Sampling Date and Number of Plots Sampled								
	Aug. 1/ 1951	Sept. 1/ 1952	Aug. 4/ 1953	Sept. 4/ 1954	Oct. 2/ 1955	Nov. 2/ 1956	Oct. 2/ 1957	Oct. 2/ 1958	Oct. 2/ 1964
					0-7 In. Depth				
None	41	9.1	7.3	5.0	4.7	4.6	5.2	4.6	5.3
Krilium - 0.1%	35	[illegible]	4.3 1/	5.7	4.7	4.1	4.9	5.1	5.7
Gypsum - [illegible] T./A.	37	-	5.2	7.0	-	4.3	4.1	4.6	5.8
Gypsum - [illegible] T./A.	[illegible]	[illegible]	[illegible]	[illegible]	3.2	3.6	4.8	5.5	4.3
Calcium Chloride - 0.8 T./A.	[illegible]	-	-	[illegible]	-	4.0	4.9	4.2	5.8
Calcium Chloride - 3.2 T./A.	29	[illegible]	[illegible] 1/	[illegible]	[illegible]	[illegible]	[illegible]	4.1	5.7
					7-18 In. Depth				
None	35	24	19	[illegible]	[illegible]	[illegible]	8.3	5.1	5.9
Krilium - 0.1%	28	8.7	6.[illegible]	6.[illegible]	[illegible]	4.9	4.9	5.5	5.7
Gypsum - 1 T./A.	32	-	12	[illegible]	-	6.2	4.6	5.2	6.8
Gypsum - 4 T./A.	28	5.0	[illegible]		[illegible]	4.2	4.6	4.8	7.3
Calcium Chloride - 0.8 T./A.	[illegible]	-	[illegible]	[illegible]	-	5.1	5.8	4.8	5.8
Calcium Chloride - 3.2 T./A.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.0	[illegible]	4.9	6.0
					18-33 In. Depth				
None	18	31	23	[illegible]	17.4	8.9	10.1	10.5	8.5
Krilium - 0.1%	14	21	12 1/	[illegible]	[illegible]	7.6	5.5	8.0	8.6
Gypsum - 1 T./A.	14	-	[illegible]	[illegible]	-	[illegible]	5.7	6.9	9.2
Gypsum - 4 T./A.	[illegible]	17	14	[illegible]	[illegible]	5.2	5.6	5.8	8.7
Calcium Chloride - 0.8 T./A.	[illegible]	-	-	[illegible]	-	9.0	7.0	5.3	7.6
Calcium Chloride - 3.2 T./A.	12	9.4	6.6 1/	[illegible]	6.8	5.5	6.3	6.4	8.2

1/ Exchangeable sodium percentage value of sample from 1 plot.
2/ Average exchangeable sodium percentage of samples from 2 replicate plots.
4/ Average exchangeable sodium percentage of samples from 4 replicate plots.

Table 2b. Exchangeable sodium percentages of the soil samples from the subbed plots pre-leached with 30 A.-in./A. of water.

Amendment	Sampling Date and Number of Plots Sampled								
	Aug. 4/ 1951	Sept. 1/ 1952	Aug. 4/ 1953	Sept. 4/ 1954	Oct. 2/ 1955	Nov. 2/ 1956	Oct. 2/ 1957	Oct. 2/ 1958	Oct. 2/ 1964
					0-7 In. Depth				
None	32	23	20	7.3	4.6	5.3	12.7	17.1	5.5
Krilium - 0.1%	30	6.5	18 1/	10.0	4.2	3.8	6.6	16.8	4.3
Gypsum - 1 T./A.	33	-	19	6.7	-	3.9	7.0	21.7	5.7
Gypsum - 4 T./A.	29	10.0	18	6.1	4.9	4.3	8.2	15.0	6.5
Calcium Chloride - 0.8 T./A.	29	-	-	8.6	-	4.0	11.1	11.7	6.0
Calcium Chloride - 3.2 T./A.	29	5.5	14 1/	8.4	4.5	5.0	10.4	21.6	6.3
					7-18 In. Depth				
None	17	30	25	10.2	11.1	6.6	13.9	18.0	7.6
Krilium - 0.1%	16	12	19 1/	9.2	11.0	4.8	11.6	13.4	6.6
Gypsum - 1 T./A.	15	-	23	8.5	-	7.4	8.7	28.9	12.1
Gypsum - 4 T./A.	16	17	18	6.2	10.9	7.2	12.9	24.4	10.7
Calcium Chloride - 0.8 T./A.	17	-	-	8.4	-	6.2	12.8	11.1	9.1
Calcium Chloride - 3.2 T./A.	15	6.7	12 1/	6.5	6.3	4.9	9.9	13.3	7.0
					18-33 In. Depth				
None	10	24	16	17	18.6	8.0	14.1	12.2	16.9
Krilium - 0.1%	8.4	15	11 1/	15	15.2	10.1	8.0	11.8	12.8
Gypsum - 1 T./A.	8.0	-	19	15	-	11.3	17.8	18.1	18.2
Gypsum - 4 T./A.	10	15	15	9.3	12.8	11.3	12.0	20.4	17.8
Calcium Chloride - 0.8 T./A.	8.4	-	-	16	-	8.4	9.0	12.9	15.3
Calcium Chloride - 3.2 T./A.	12	12	12 1/	12	11.8	8.8	11.9	9.9	13.3

1/ Exchangeable sodium percentage value of sample from 1 plot.
2/ Average exchangeable sodium percentage of samples from 2 replicate plots.
4/ Average exchangeable sodium percentage of samples from 4 replicate plots.

Table 2c. Exchangeable sodium percentages of the soil samples from the drained and subbed plots pre-leached with 12 A.-in./A. of water.

Amendment	Sampling Date and Number of Plots									
	DRAINED AREA					SUBBED AREA				
	Aug. 4/ 1951	Aug. 4/ 1953	Sept. 4/ 1954	Nov. 1/ 1956	Oct. 1/ 1957	Aug. 4/ 1951	Aug. 4/ 1953	Sept. 4/ 1954	Nov. 1/ 1956	Oct. 1/ 1957
					0-7 In. Depth					
None	[illegible]	4.8	6.[illegible]	-	-	[illegible]	16	5.3	-	-
Krilium - 0.1%	25	-	7.1	-	-	[illegible]	-	8.7	-	-
Gypsum - 1 T./A.	31	4.7	[illegible]	-	[illegible]	31	2[illegible]	4.9	4.7	6.4
Gypsum - 4 T./A.	[illegible]	4.8	5.7	-	-	28	19	5.3	-	-
Calcium Chloride - 0.8 T./A.	29	-	[illegible]	[illegible]	[illegible]	36	-	7.6	4.4	6.1
Calcium Chloride - 3.2 T./A.	[illegible]	-	[illegible]	-	-	36	-	8.4	-	-
					7-18 In. Depth					
None	24	14	[illegible]	-	-	22	27	6.4	-	-
Krilium - 0.1%	2[illegible]	-	7.[illegible]	-	-	19	-	11.1	-	-
Gypsum - 1 T./A.	27	16	5.1	[illegible]	[illegible]	18	26	6.2	4.6	8.5
Gypsum - 4 T./A.	25	12	5.[illegible]	-	-	18	24	4.6	-	-
Calcium Chloride - 0.8 T./A.	24	-	8.7	[illegible]	[illegible]	19	-	7.9	7.1	12.4
Calcium Chloride - 3.2 T./A.	25	-	6.[illegible]	-	-	26	-	9.8	-	-
					18-33 In. Depth					
None	14	18	10.7	-	-	11	17	14	-	-
Krilium - 0.1%	11	-	13.[illegible]	-	-	10	-	17	-	-
Gypsum - 1 T./A.	15	21	11.[illegible]	9.[illegible]	6.[illegible]	11	15	13	11.7	13.7
Gypsum - 4 T./A.	13	18	6.6	-	-	10	16	6.9	-	-
Calcium Chloride - 0.8 T./A.	10	-	15.8	5.[illegible]	5.5	12	-	17	10.0	18.4
Calcium Chloride - 3.2 T./A.	12	-	12.1	-	-	14	-	15	-	-

1/ Exchangeable sodium percentage value of sample from 1 plot.
4/ Average exchangeable sodium percentage of samples from 4 replicate plots.

Table 2d. Summary of exchangeable sodium percentages and statistical analysis in 1951 before reclamation and after complete resampling in 1954.

1951

Amendments	DRAINED PLOTS Depth-Inches 0-7	7-18	18-33	Avg.	SUBBED PLOTS Depth-Inches 0-7	7-18	18-33	Avg.
No Amendment	36.5	29.0	16.1	27.2	28.4	19.7	10.4	19.5
Krilium	31.7	26.2	11.5	23.4	30.5	17.3	9.3	19.0
Gypsum - 1 T./A.	34.2	29.3	14.1	25.9	31.7	16.7	9.2	19.2
Gypsum - 4 T./A.	35.0	26.6	13.0	24.9	28.7	16.6	9.8	18.4
$CaCl_2$ - 0.8 T./A.	27.5	21.9	9.8	19.7	32.9	17.8	10.0	20.2
$CaCl_2$ - 3.2 T./A.	31.6	24.7	11.9	22.7	33.4	20.7	12.8	22.3
Average	32.7	26.3	12.9	24.0	30.9	18.1	10.3	19.8
Leach				Avg.				Avg.
12 A.-in./A.	31.2	25.3	12.5	23.0	31.4	20.3	11.3	21.0
30 A.-in./A.	34.0	28.0	13.5	25.0	30.0	16.0	9.5	18.5
Coefficient of Variation			25.6%				27.2%	
Amendment LSD .05			3.5%		Leach LSD .05		1.8%	
.01			4.7%		.01		2.3%	
Depth .05			2.5%		Depth .05		2.2%	
.01			3.3%		.01		2.8%	

1954

Amendments	DRAINED PLOTS Depth-Inches 0-7	7-18	18-33	Avg.	SUBBED PLOTS Depth-Inches 0-7	7-18	18-33	Avg.
No Amendment	7.5	7.5	13.6	9.5	6.3	8.3	15.3	10.0
Krilium	7.9	6.6	12.8	9.1	9.3	10.1	16.2	11.9
Gypsum - 1 T./A.	6.5	5.8	11.0	7.8	5.8	7.3	14.3	9.1
Gypsum - 4 T./A.	6.0	4.7	6.2	5.6	5.7	5.4	8.1	6.4
$CaCl_2$ - 0.8 T./A.	7.7	7.4	12.8	9.3	8.1	8.1	16.4	10.9
$CaCl_2$ - 3.2 T./A.	8.3	6.7	10.2	8.4	8.4	8.1	13.3	9.9
Average	7.3	6.4	11.1	8.3	7.3	7.9	13.9	9.7
Leach				Avg.				Avg.
21 A.-in./A.	7.0	6.3	12.5	8.3	6.7	7.7	13.8	9.4
30 A.-in./A.	7.6	6.6	9.9	8.2	7.9	8.2	14.0	10.0
Coefficient of Variation			29.6%				30.5%	
Amendment LSD .05			1.4%				1.7%	
.01			1.9%				2.2%	
Depth LSD .05			1.0%				1.2%	
.01			1.3%				1.6%	

Table 3. Water table depths in the plot area, 1952-1964.

Year	Drained Area			Subbed Area			Outside the Plot Areas	
	May 15	Oct. 1	Avg.*	May 15	Oct. 1	Avg.*	Apr. 1	Oct. 1
1952	5.1	6.2	5.7	1.3	2.6	2.1	5.0	3.5
1953	4.6	6.2	5.4	1.5	3.2	2.7	3.0	5.0
1954	7.0	9.1	8.0	4.0	5.7	4.6	4.7	5.5
1955	7.6	10.4	9.7	4.7	6.2	5.4	5.9	-
1956	7.9	10.3	9.8	4.7	6.2	5.2	6.0	6.7
1957	9.8	7.8	9.7	4.7	2.5	3.4	6.4	4.0
1958	6.6	8.2	7.6	2.9	3.1	3.1	3.7	5.0
1959	4.2	6.2	5.0	4.0	6.0	4.7	4.3	6.0
1960	5.0	5.6	5.4	4.8	5.4	5.1	5.0	5.6
1961	4.5	5.0	4.7	5.1	5.0	4.5	4.6	5.1
1962	4.2	4.8	4.6	4.0	4.3	4.2	4.2	4.8
1963	4.2	5.1	5.3	4.3	5.8	5.2	4.1	6.1
1964	5.3	6.4	5.9	5.3	6.2	5.7	5.5	6.3

*Average of weekly water table [illegible] measurements taken during the period of May 15-Oct. 1

Table 4. Analy[illegible] irrigation.

	Aug. 1956	Aug. 1962	Sept. 1964	Oct. 1957	Oct. 1964
Cations - me./l.					
Calcium plus Magnesium	[illegible]	7.85	7.54	8.51	7.1	5.5
Magnesium	2.0[illegible]					2.0
Sodium	[illegible]	[illegible]	[illegible]	4.12	3.6	5.0
Potassium	-	-	-	-	-	0.3
Anions - me./l.						
Carbonate	trace	0.80	0.60	0	0	1.2
Bicarbonate	[illegible]	1.70	[illegible]	[illegible]	4.51	4.3
Sulfate	[illegible]	-	-	-	-	4.4
Chloride	[illegible]	2.05	1.92	2.10	-	1.7
Nitrate	[illegible]	[illegible]	[illegible]	0.10	-	0.27
Conductivity - EC x 10^6 @ 25°C.	[illegible]	1100	1060	1180	1050	1225
pH	7.9	-	-	-	7.5	8.6
Sodium - %	[illegible]	32	34	33	34	39
Sodium-Adsorption-Ratio	.90	1.67	[illegible]	2.00	1.92	2.58
Boron - Ppm.	[illegible]	0.21	0.16	0.12	-	-
Dissolved Solids - Tons per acre foot	1.08	1.07	1.03	1.15	1.02	1.19

Table 5. Summary of amount (A.-in./A.) and number[1/] of crop and post-harvest irrigations.

Year	Crop	DRAINED AREA				SUBBED AREA			
		Crop Irrigation		Post-Harvest		Crop Irrigation		Post-Harvest	
		Low Rate	High Rate	Low Rate	High Rate	Low Rate	High Rate	Low Rate	High Rate
1952	Barley (With Sweetclover)	- 20(7) -		- 4(1) -		- 17(6) -		- 4(1) -	
1953	Sweetclover	- 17(5) -		- 4(1) -		- 14(4) -		- 4(1) -	
1954	Potatoes	- 45(15)* -		- None -		- 42(14)* -		- None -	
1955	Barley (With Alfalfa)	24(6)*	48(12)*	12(3)**	4(1)**	20(5)*	32(8)*	12(3)**	4(1)**
1956	Alfalfa (3 Cuts)	- 32(8) -		- 12(3)** -		- 32(8) -		- 12(3)** -	
1957	Alfalfa (2 Cuts)	20(5)	8(2)	12(3)**	12(3)**	4(1)	12(3)	4(1)	None
1958	Alfalfa (3 Cuts)	12(3)	24(6)	8(2)*	12(3)*	None	8(2)	8(2)**	4(1)**
1959	Alfalfa (2 Cuts)	None	12(3)	8(2)	12(3)	None	12(3)	8(2)**	12(3)**
1960	Alfalfa (2 Cuts)	- 12(3) -		- 4(1) -		- 12(3) -		- 4(1) -	
1961	Barley	- 20(5) -		- None -		- 20(5) -		- None -	
1962	Barley	12(3)	24(6)	- None -		8(2)	16(4)	- None -	
1963	Oats	- 30(7)* -		- None -		- 30(7)* -		- None -	
1964	Oats	- 16(4)* -		- None -		- 12(3)* -		- None -	

1/ Number of irrigations in parentheses.

*Includes 1 irrigation before planting the crop.
**Includes 1 irrigation late in Oct. to prevent winter-kill.

Table 6. Summary of fertilizers and rates applied on the crops.

1952	Barley (started with Sweetclover) - 150 lbs./A. P_2O_5 (Treble superphosphate) on all plots before planting.
1953	Sweetclover chopped and plowed under (fall); 25 lbs./A. N applied.
1954	Potatoes - 25 lbs./A. N and 200 lbs./A. P_2O_5 before planting potatoes.
1955	Barley - 40 lbs./A. N and 300 lbs./A. P_2O_5.
1961	Barley - 40 lbs./A. N (Urea).
1962	Barley - Fertility trial - rates: 0, 50 N, 100 N, 50 N + 50 P_2O_5, 100 N + 50 P_2O_5 (Ammonium nitrate and treble superphosphate).
1963	Oats - 70 N and 40 lbs./A. P_2O_5 (Ammonium nitrate and treble superphosphate.)
1964	Oats - 70 lbs./A. N (Ammonium nitrate).

Table 7. Average 1952 barley grain yields for amendment and leaching treatments on the plots.

	DRAINED AREA BARLEY YIELD			SUBBED AREA BARLEY YIELD		
	Leach			Leach		
Amendments	12 A.-in./A.	30 A.-in./A.	Avg.	12 A.-in./A.	30 A.-in./A.	Avg.
	Bushels per Acre			Bushels per Acre		
None	8.2	16.6	12.4	24.1	31.7	27.9
Krilium - 0.1%	12.4	18.3	15.4	52.1	34.1	43.1
Gypsum - 1 T./A.	11.9	15.9	13.9	42.9	46.2	44.6
Gypsum - 4 T./A.	13.7	16.2	15.0	54.4	44.7	49.6
$CaCl_2$ - 0.8 T./A.	10.8	12.6	11.7	50.8	35.7	43.3
$CaCl_2$ - 3.2 T./A.	12.9	13.4	13.2	51.1	46.0	48.6
Average	11.7	15.5	13.6	45.9	39.7	42.8
Coefficient of Variation		36.3%			26.8%	
Amendment LSD .05		Not Significant			11.6 Bu./A.	
.01		Not Significant			15.6 Bu./A.	
Leach LSD .05		2.8 Bu./A.			Not Significant	

Table 8. Average 1953 sweetclover hay yields (oven-dry weight) for 1952 amendment and leaching treatments on the plots.

Amendments	DRAINED AREA CLOVER YIELD Leach 12 A.-in./A.	30 A.-in./A.	Avg.	SUBBED AREA CLOVER YIELD Leach 12 A.-in./A.	30 A.-in./A.	Avg.
	Tons per Acre			Tons per Acre		
None	1.91	1.21	1.56	2.75	2.97	2.86
Krilium - 0.1%	1.88	1.84	1.86	2.87	2.96	2.96
Gypsum - 1 T./A.	1.98	2.25	2.11	2.65	3.19	2.92
Gypsum - 4 T./A.	2.18	2.22	2.20	2.66	3.23	2.95
$CaCl_2$ - 0.8 T./A.	1.64	2.21	1.93	3.16	3.01	3.08
$CaCl_2$ - 3.2 T./A.	2.36	2.34	2.35	2.82	3.23	3.02
Average	1.99	2.01	2.00	2.82	3.10	2.96
Coefficient of Variation		28.5%			8.9%	
Leach LSD .01		Not Significant			0.20 T./A.	

Table 9. Average 1954 Red McClure potato yields for the 1952 amendment and leaching* treatments on the plots.

Amendment	DRAINED AREA POTATO YIELD Leach 21 A.-in./A.	30 A.-in./A.	Avg.	SUBBED AREA POTATO YIELD Leach 21 A.-in./A.	30 A.-in./A.	Avg.
	100-pound Sacks per Acre			100-pound Sacks per Acre		
None	165.8	164.8	165.3	180.3	201.8	191.0
Krilium - 0.1 %	163.3	186.3	174.8	219.0	234.0	226.5
Gypsum - 1 T./A.	177.3	179.3	178.3	199.3	229.5	214.4
Gypsum - 4 T./A.	182.0	190.0	186.0	225.0	240.0	232.5
$CaCl_2$ - 0.8 T./A.	161.8	161.0	161.4	223.0	242.0	232.5
$CaCl_2$ - 3.2 T./A.	173.0	156.3	164.6	232.0	276.3	254.1
Average	170.5	172.9	171.7	213.1	237.3	225.2
Coefficient of Variation		16.9%			11.5%	
Amendment LSD .05		Not Significant			26.5 Sacks/A.	
.01		Not Significant			35.6 Sacks/A.	
Leach .05		Not Significant			20.2 Sacks/A.	

*An additional 9 A.-in./A. of leaching water applied on the plots initially leached with 12 A.-in./A.

Table 10. Average 1955 Trebi barley grain yields for the 1952 amendment and leaching treatments and 1955 irrigation rates.

Amendment	Leach	DRAINED AREA BARLEY YIELD Irrigation 24 A.-in.	48 A.-in.	Avg.	SUBBED AREA BARLEY YIELD Irrigation 20 A.-in.	32 A.-in.	Avg.
	A.-In./A.	Bushels per Acre			Bushels per Acre		
None	21	5.1	7.3	6.2	5.2	7.9	6.6
None	30	6.8	4.4	5.6	6.2	11.2	8.7
Average		5.9	5.8	5.9	5.7	9.6	7.7
Krilium - 0.1%	21	11.8	9.5	10.7	16.8	14.1	15.5
Krilium - 0.1%	30	6.1	9.3	7.7	6.9	9.9	8.4
Average		8.9	9.4	9.2	11.9	12.0	12.0
Gypsum - 1 T./A.	21	8.5	12.0	10.3	13.1	14.0	13.6
Gypsum - 1 T./A.	30	7.0	4.3	5.7	12.1	12.2	12.2
Average		7.8	8.1	8.0	12.6	13.1	12.9
Gypsum - 4 T./A.	21	13.1	9.2	11.2	9.7	30.7	20.2
Gypsum - 4 T./A.	30	7.0	8.7	7.9	9.6	25.4	17.5
Average		10.0	8.9	9.5	9.6	28.0	18.8
$CaCl_2$ - 0.8 T./A.	21	9.7	4.5	7.1	9.4	13.2	11.3
$CaCl_2$ - 0.8 T./A.	30	8.1	6.1	7.1	15.5	26.0	20.8
Average		8.9	5.3	7.1	12.4	19.6	16.0
$CaCl_2$ - 3.2 T./A.	21	9.5	7.3	8.4	9.4	15.9	12.7
$CaCl_2$ - 3.2 T./A.	30	6.1	7.2	6.7	18.8	16.6	17.7
Average		7.8	7.2	7.5	14.1	16.2	15.4
Overall Average		8.2	7.5	7.9	11.0	16.4	13.7
Coefficient of Variation - Main Plots (Irr.)				70.0%			68.1%
Split Plots (Amend. and Leach)				47.0%			31.3%
Leach	LSD .05	2.2 Bu./A.			Not Significant		

Table 11. Average 1956 Ranger alfalfa hay yields (3 cuttings , oven-dry weight) for amendmen and leaching treatments and stand difference due to the 1955 differential irrigation rates.

Amendment	Leach	DRAINED AREA ALFALFA YIELD Irrigation 24 A.-in.	48 A.-in.	Avg.	SUBBED AREA ALFALFA YIELD Irrigation 20 A.-in.	32 A.-in.	Avg.
	A.-in./A.	Tons per Acre			Tons per Acre		
None	21	2.50	4.01	3.25	3.63	4.06	3.85
None	30	3.07	3.70	3.38	4.46	4.74	4.60
Average		2.78	3.86	3.32	4.01	4.40	4.22
Krilium - 0.1%	21	4.19	3.99	4.09	4.14	6.02	5.08
Krilium - 0.1%	30	3.62	4.40	4.01	5.40	6.55	5.97
Average		3.90	4.19	4.05	4.77	6.28	5.53
Gypsum - 1 T./A.	21	3.10	4.38	3.74	4.36	4.33	4.34
Gypsum - 1 T./A.	30	3.33	3.56	3.44	3.92	4.94	4.43
Average		3.21	3.97	3.59	4.14	4.63	4.38
Gypsum - 4 T./A.	21	3.73	4.52	4.12	4.12	5.18	4.65
Gypsum - 4 T./A.	30	2.82	4.55	3.68	4.87	5.79	5.33
Average		3.27	4.53	3.90	4.49	5.48	4.99
$CaCl_2$ - 0.8 T./A.	21	2.84	3.64	3.24	4.09	4.81	4.45
$CaCl_2$ - 0.8 T./A.	30	2.80	3.75	3.27	4.87	4.60	4.74
Average		2.82	3.70	3.26	4.48	4.70	4.59
$CaCl_2$ - 3.2 T./A.	21	3.59	4.67	4.13	5.14	4.40	4.77
$CaCl_2$ - 3.2 T./A.	30	3.72	4.43	4.08	5.25	5.00	5.12
Average		3.66	4.55	4.10	5.19	4.70	4.94
Overall Average		3.27	4.13	3.70	4.52	5.03	4.78
Coefficient of Variation - Main Plots (Irr.)				30.0%			12.0%
Split Plots (Amend. and Leach)				14.5%			18.9%
Amendment LSD .05			0.55 T./A.		LSD .10	0.77 T./A.	

Table 12. Average 1957 alfalfa hay yields (2 cuttings, oven-dry weight) for the amendment and leaching treatments and 1957 irrigation rates.

Amendment	Leach	DRAINED AREA ALFALFA YIELD Irrigation 8 A.-in.	20 A.-in.	Avg.	SUBBED AREA ALFALFA YIELD Irrigation 4 A.-in.	12 A.-in.	Avg.
	A.-in./A.	Tons per Acre			Tons per Acre		
None	21	3.14	3.70	3.42	3.86	4.20	4.03
None	30	3.20	3.58	3.39	4.06	3.41	3.73
Average		3.17	3.64	3.40	3.96	3.80	3.88
Krilium - 0.1%	21	2.43	3.84	3.13	3.86	3.56	3.71
Krilium - 0.1%	30	3.01	3.97	3.49	4.27	3.79	4.03
Average		2.72	3.91	3.31	4.07	3.67	3.87
Gypsum - 1 T./A.	21	2.99	3.68	3.33	3.59	3.47	3.53
Gypsum - 1 T./A.	30	2.87	3.62	3.25	3.60	3.80	3.70
Average		2.93	3.65	3.29	3.59	3.63	3.61
Gypsum - 4 T./A.	21	2.46	4.15	3.31	4.08	3.99	4.03
Gypsum - 4 T./A.	30	3.09	3.16	3.13	3.32	3.56	3.44
Average		2.78	3.66	3.22	3.70	3.77	3.74
$CaCl_2$ - 0.8 T./A.	21	3.17	3.89	3.53	3.94	3.72	3.83
$CaCl_2$ - 0.8 T./A.	30	2.61	3.86	3.24	3.67	3.94	3.80
Average		2.89	3.87	3.38	3.80	3.83	3.81
$CaCl_2$ - 3.2 T./A.	21	3.24	3.94	3.59	4.14	3.82	3.98
$CaCl_2$ - 3.2 T./A.	30	3.35	3.81	3.58	4.08	4.19	4.13
Average		3.29	3.87	3.58	4.11	4.00	4.06
Overall Average		2.96	3.76	3.36	3.87	3.78	3.83
Coefficient of Variation - Main Plots (Irr.)				36.9%			13.6%
Split Plots (Amend. and Leach)				9.5%			11.0%

Table 13. Average 1958 alfalfa hay yields (3 cuttings, oven-dry weight) for the amendment and leaching treatments and the 1958 irrigation rates.

Amendment	Leach	DRAINED AREA ALFALFA YIELD Irrigation 12 A.-in.	24 A.-in.	Avg.	SUBBED AREA ALFALFA YIELD Irrigation None	8 A.-in.	Avg.
	A.-in./A.	Tons per Acre			Tons per Acre		
None	21	4.21	4.99	4.60	5.38	5.23	5.31
None	30	3.79	5.12	4.46	5.58	4.89	5.24
Average		4.00	5.06	4.53	5.48	5.06	5.27
Krilium - 0.1%	21	3.48	5.12	4.30	5.33	4.67	5.00
Krilium - 0.1%	30	4.21	5.24	4.73	5.10	5.57	5.34
Average		3.84	5.18	4.51	5.22	5.12	5.17
Gypsum 1 T./A.	21	3.53	5.05	4.29	5.08	4.89	4.99
Gypsum 1 T./A.	30	4.00	5.25	4.63	5.48	5.06	5.27
Average		3.77	5.15	4.46	5.28	4.97	5.13
Gypsum 4 T./A.	21	3.11	4.70	3.91	5.34	5.32	5.33
Gypsum 4 T./A.	30	3.35	5.05	4.20	5.63	5.19	5.41
Average		3.23	4.87	4.05	5.48	5.26	5.37
$CaCl_2$ - 0.8 T./A.	21	4.11	4.67	4.39	5.17	4.86	5.02
$CaCl_2$ - 0.8 T./A.	30	3.60	5.06	4.33	5.75	5.58	5.67
Average		3.85	4.86	4.36	5.46	5.22	5.34
$CaCl_2$ - 3.2 T./A.	21	3.86	5.33	4.60	5.14	5.40	5.27
$CaCl_2$ - 3.2 T./A.	30	4.15	5.13	4.64	5.13	5.48	5.31
Average		4.00	5.23	4.62	5.14	5.44	5.29
Overall Average		3.78	5.06	4.42	5.34	5.18	5.26
Coefficient of Variation - Main Plots (Irr.)				17.2%			0.9%
Split Plots (Amend. and Leach)				8.4%			6.5%
Leach	LSD .05		Not Significant			0.20 T./A.	

Table 14. Average 1959 alfalfa hay yields (2 cuttings, oven-dry weight) for the 1952 amendment and leaching treatments and 1959 irrigation rates.

Amendment	Leach	DRAINED AREA* ALFALFA YIELD Irrigation None	12 A.-in.	Avg.	SUBBED AREA* ALFALFA YIELD Irrigation None	12 A.-in.	Avg.
	A.-in./A.	Tons per Acre			Tons per Acre		
None	21	3.00	3.25	3.12	3.18	3.26	3.22
None	30	3.23	3.15	3.19	3.15	3.32	3.23
Average		3.11	3.20	3.15	3.17	3.29	3.23
Krilium - 0.1%	21	3.23	3.40	3.31	2.23	3.34	2.78
Krilium - 0.1%	30	2.93	3.64	3.28	3.21	3.34	3.28
Average		3.08	3.52	3.30	2.72	3.34	3.03
Gypsum - 1 T./A.	21	3.18	3.65	3.42	3.03	3.34	3.19
Gypsum - 1 T./A.	30	3.18	3.23	3.20	2.89	3.00	2.95
Average		3.18	3.44	3.31	2.96	3.17	3.07
Gypsum - 4 T./A.	21	3.34	3.44	3.39	3.03	3.39	3.21
Gypsum - 4 T./A.	30	3.00	3.35	3.17	1.70	3.05	2.37
Average		3.17	3.39	3.28	2.36	3.22	2.79
$CaCl_2$ - 0.8 T./A.	21	3.07	3.35	3.21	2.81	3.15	2.98
$CaCl_2$ - 0.8 T./A.	30	3.06	3.44	3.25	2.81	3.46	3.13
Average		3.06	3.39	3.23	2.81	3.30	3.05
$CaCl_2$ - 3.2 T./A.	21	3.43	3.45	3.44	3.11	3.67	3.39
$CaCl_2$ - 3.2 T./A.	30	2.94	3.37	3.16	3.21	3.16	3.19
Average		3.18	3.41	3.30	3.16	3.41	3.29
Overall Average		3.13	3.39	3.26	2.86	3.29	3.07
Coefficient of Variation - Main Plots (Irr.)				48.0%			4.6%
Split Plots (Amend. and Leach)				8.9%			11.7%
Irrigation	LSD .01		Not Significant			0.1 T./A.	

*Pumping to produce a water table difference between areas was discontinued in 1959.

Table 15. Average 1960 alfalfa hay yields (2 cuttings, oven-dry weight) for 1952 amendment treatments.

Amendment	DRAINED AREA* ALFALFA YIELD	SUBBED AREA* ALFALFA YIELD
	Tons per Acre	Tons per Acre
None	3.9	3.7
Krilium - 0.1%	4.1	4.1
Gypsum - 1 T./A.	4.3	4.1
Gypsum - 4 T./A.	4.1	3.8
$CaCl_2$ - 0.8 T./A.	4.2	3.8
$CaCl_2$ - 3.2 T./A.	4.1	3.4
Average	4.1	3.8

Table 16. Average 1961 Otis barley yields for 1952 amendment and leaching treatments.

Amendment	DRAINED AREA* BARLEY YIELD			SUBBED AREA* BARLEY YIELD		
	Leach (A.-in./A.)			Leach (A.-in./A.)		
	21	30	Avg.	21	30	Avg.
	Bushels per Acre			Bushels per Acre		
None	48.1	40.8	44.4	56.8	70.8	63.8
Krilium - 0.1%	60.4	58.1	59.2	71.5	77.5	74.5
Gypsum - 1 T./A.	50.4	52.8	51.6	63.8	77.7	70.8
Gypsum - 4 T./A.	53.3	56.9	55.1	72.8	82.9	77.8
$CaCl_2$ - 0.8 T./A.	49.8	49.2	49.5	73.0	69.1	71.1
$CaCl_2$ - 3.2 T./A.	49.3	48.1	48.7	73.8	77.8	75.8
Average	51.9	51.0	51.4	68.6	76.0	72.3

Table 17. Average 1962 Otis barley grain yields for the fertilizer and irrigation rates on the reclaimed plots.

Fertilizer Application	DRAINED AREA* BARLEY YIELD			SUBBED AREA* BARLEY YIELD		
	Irrigation (A.-in./A.)			Irrigation (A.-in./A.)		
	16	24	Avg.	8	16	Avg.
Pounds per Acre	Bushels per Acre			Bushels per Acre		
0	47	59	53	72	60	66
50 N	69	77	73	73	85	79
100 N	56	87	72	83	91	87
50 N + 50 P_2O_5	71	71	71	71	79	74
100 N + 50 P_2O_5	85	77	81	81	90	86
Average	65	74	69	76	80	78
Fertilizer and Rate LSD .05			8 Bu./A.			12 Bu./A.
.01			9 Bu./A.			Not Significant
Fertilizer x Irrigation LSD .05			12 Bu./A.			Not Significant
.01			15 Bu./A.			Not Significant

Table 18. Average 1963 Park oat grain yields for the 1952 amendment and leaching treaments and 1962 fall chiseling treatment.

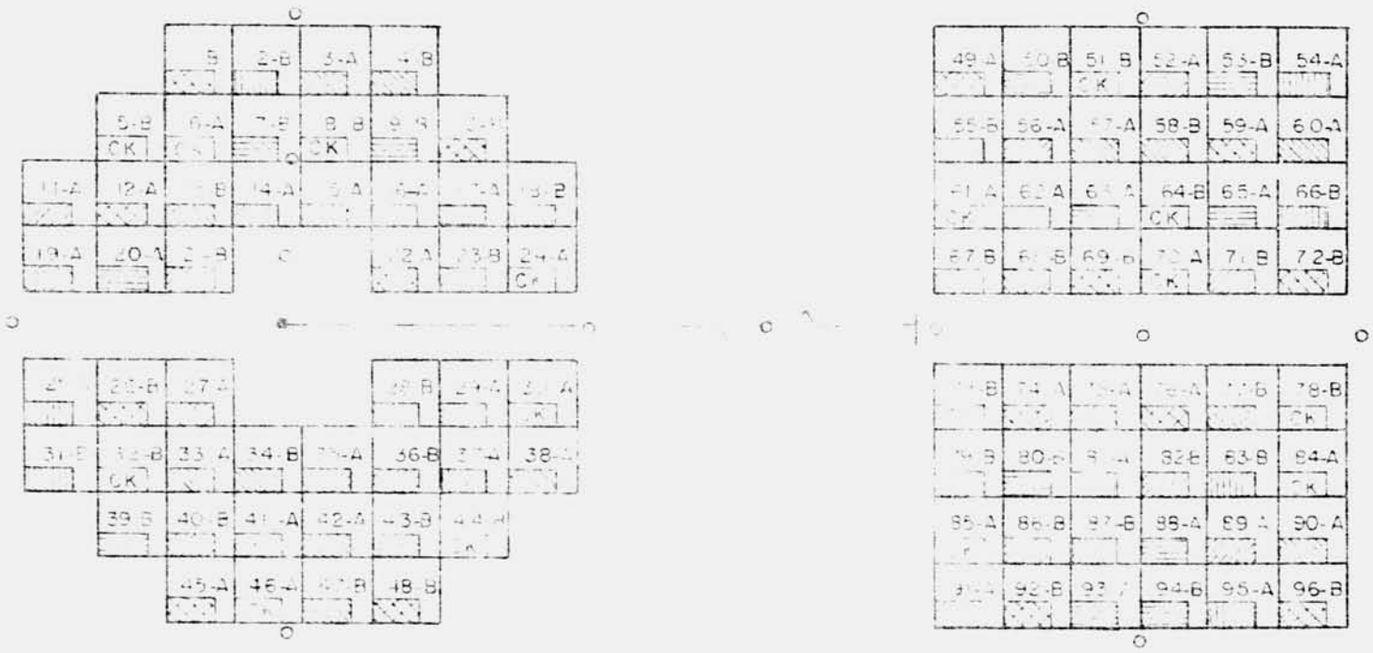
Amendment	Leach	DRAINED AREA* OAT YIELD			SUBBED AREA* OAT YIELD		
		Not Chiseled	Chiseled	Avg.	Not Chiseled	Chiseled	Avg.
	A.-in./A.	Bushels per Acre			Bushels per Acre		
None	21	78.0	101.2	86.9	127.2	114.9	121.0
None	30	89.8	108.8	99.3	125.6	116.8	121.2
Average		83.9	105.0	94.5	123.9	115.8	121.1
Krilium - 0.1%	21	99.7	103.4	101.5	107.7	95.1	101.4
Krilium - 0.1%	30	101.8	139.8	120.8	146.5	135.8	141.3
Average		100.7	121.6	111.2	127.1	115.4	121.2
Gypsum - 1 T./A.	21	100.2	86.5	93.3	127.2	138.5	132.8
Gypsum - 1 T./A.	30	101.3	105.3	103.3	105.6	122.1	113.8
Average		100.7	95.9	98.3	116.4	130.3	123.3
Gypsum - 4 T./A.	21	88.9	111.1	100.0	133.1	124.8	128.9
Gypsum - 4 T./A.	30	109.8	94.6	102.2	136.1	130.4	133.2
Average		99.4	102.9	101.0	134.6	127.6	131.1
$CaCl_2$ - 0.8 T./A.	21	98.6	88.7	93.6	146.2	129.4	137.8
$CaCl_2$ - 0.8 T./A.	30	97.2	115.7	106.5	126.5	119.7	123.1
Average		97.9	102.2	100.0	136.3	124.5	130.4
$CaCl_2$ - 3.2 T./A.	21	114.1	103.2	108.6	125.6	131.8	128.7
$CaCl_2$ - 3.2 T./A.	30	97.0	106.6	101.8	136.8	125.9	131.4
Average		105.5	104.9	105.2	131.2	128.8	130.0
Amendment Average		98.0	105.4	101.7	128.7	123.7	126.2
21" Leach Average		96.6	99.0	97.8	127.8	122.4	125.1
30" Leach Average		99.5	111.8	105.6	129.5	125.1	127.3
Amendment x Leach	LSD .05		Not Significant			25.5 Bu./A.	

*Continuous pumping to produce water table difference discontinued.

Table 19. Average 1964 Park oat grain yields for the 1962 fall chiseling treatment.

Tillage Treatment	DRAINED AREA* OAT YIELD	SUBBED AREA OAT YIELD
	Bushels per Acre	Bushels per Acre
Not Chiseled	42.4	39.2
30-In. Chisel	41.1	34.7
Average	41.7	37.0
Tillage LSD .05	Not Significant	3.9 Bu./A.

*Continuous pumping to produce water table difference discontinued.



GENERAL

- ● Control Well
- ○ Observation Well
- -- 1 Thru. 48 Low Water Table (Drained) Plots
- – 49 Thru 96 High Water Table (Subbed) Plots
- – Plots - 20' x 20'
- – Main East West Alley 25' Wide
- – Other Alleys 10' Wide

1952 CHEMICAL TREATMENTS

- Check-No Amendment
- Kr[illegible]
- Gypsum - 1 T/A
- Gypsum - 4 T/A
- $CaCl_2$ - 0.8 T/A
- $CaCl_2$ - 3.2 T/A

1952 PRE-LEACHING TREATMENTS

A - 12 A - in/A.

B - 30 A. - in/A

Figure 1a. Mosca experimental reclamation plot diagram and treatments. (APPENDIX)