Reclamation of a Saline-Alkali Soil by Leaching and Gypsum Treatments Using Sugar Beets as an Indicator Crop[1]

Louis C. BOAWN, FRED TURNER, JR., C. D. MOODIE, AND C. A. BOWER[2]

Introduction

Several rather extensive areas of alkali[3] soils occur in the Yakima Valley of Washington. From the standpoint of topography, texture, and profile depth, these soils are highly suitable for irrigation agriculture and, were it not for their alkali nature, would probably be among the most productive soils of the area. Attempts are being made to farm many of these soils, but at best, production is uncertain and reduced because of the alkali "spots" where crops fail to grow.

The purpose of the experiment reported in this paper, which is part of a more comprehensive research program, was to determine the effect of leaching and gypsum treatments upon the removal of exchangeable sodium and soluble salts and finally the effect of these treatments upon crop growth. Ultimately, the goal of the research program is to determine the most direct and economical means of bringing the alkali soils of this area into useful production.

Sugar beets were used as an indicator crop. Because of their high cash value, salt tolerance, and possible benefit from the sodium ion as a nutrient, they should be a desirable crop for farmers of the area to produce.

Procedure

The experimental plots were located about three miles south of Toppenish, Washington, on Umapine fine sandy loam. Sixteen 20- by 30-foot plots were established on alkali spots which were reasonably uniform and in all cases devoid of vegetation. The surface six inches of soil in the plots had a pH of 9.5 to 10.0, an exchangeable sodium-percentage of 60 to 70, and an electrical conductivity of the saturation extract greater than 10 millimhos per centimeter. All of these saline and alkali properties decreased gradually with depth and approached values characteristic of a normal soil in the 24-36 inch layer.

During 1949, eight of the 16 plots were diked and flooded with water in six-inch increments until a total of 30 inches of water had been applied. The effect of this flooding upon exchangeable sodium and salt removal was followed by analyses of soil samples taken before, during and after the flooding operations.

[1] Scientific Paper No. 1086, Washington Agricultural Experiment Stations, Pullman. Project No. 882. This paper is based on a thesis submitted by the senior author to The State College of Washington in partial fulfillment of the requirements for the degree of Master of Science in Agriculture (1).[4] The research was performed under a cooperative agreement between the Utah-Idaho Sugar Company, the Washington Agricultural Experiment Stations, and the Bureau of Plant Industry, Soils, and Agricultural Engineering, U.S.D.A. The authors wish to acknowledge their indebtedness to the Utah-Idaho Sugar Company for the research grant and assistance with field operations. Appreciation is also extended to the many individuals of the cooperating agencies for their advice and guidance.

[2] Formerly Research Assistant in Soils, The State College of Washington, now Soil Scientist, Division of Soil Management and Irrigation, U.S.D.A.; Soil Scientist, Division of Soil Management and Irrigation, U.S.D.A., now on leave to the U. S. Air Force; Associate Soil Scientist, the State College of Washington; and, Senior Soil Scientist, the U. S. Salinity Laboratory, U.S.D.A.

[3] The term *alkali* is used in this paper to designate a soil having an exchangeable-sodium - percentage exceeding 15.

[4] Numbers in parentheses refer to literature cited.

In the spring of 1950, the plot dikes were broken down and the entire field planted to sugar beets. The customary cultural practices for the area were followed except that pre-emergence irrigation (2) was applied. Previous to planting, one-half of the flooded plots and one-half of the unflooded plots were treated with agricultural gypsum at a rate of 10.4 tons per acre. Thus four treatments were established: (a) no treatment, (b) leaching-without-gypsum, (c) leaching-plus-gypsum, and (d) gypsum alone. Soil changes resulting from these treatments during the growing season were followed through analyses of soil samples taken before planting and at harvest time. The effect of the treatments upon sugar beet growth was determined by stand counts before thinning, after thinning, and at harvest time, and by tonnage yield.

Results and Discussion

Effects of Leaching, Gypsum, and Furrow Irrigation upon Soluble Salts, Soil Reaction, and Exchangeable Sodium

Effect of Leaching.—Soluble salts were rapidly removed from the surface three feet of soil as a result of leaching (Figure 1). After flooding with 12 inches of water, the surface foot of soil had been reduced to a non-saline condition, but a considerable portion of these salts had accumulated in the 12-36 inch layer. Following another 12 inches of flooding, however, the salts had been moved beyond the 36-inch depth, leaving the upper three feet of soil free of excess salinity. The final six-inch application of water produced no significant change in salt content at any depth; the electrical conductivity of the saturation abstracts tends to approach a rather high

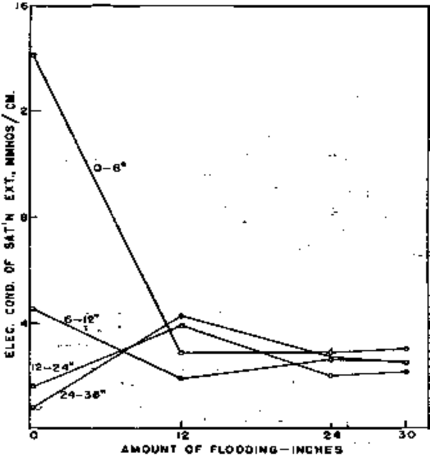

Figure 1.—Soluble salt content (conductivity of saturation extracts) of four soil layers as affected by leaching (averages of four plots).

minimum of around two and five-tenths millimhos per centimeter. Essentially no change in pH occurred at any depth as a result of leaching.

The effect of leaching upon the replacement and movement of exchangeable sodium is shown in Figure 2. Exchangeable sodium was not readily removed by leaching, and even after 30 inches of flooding only about 17 percent of the exchangeable sodium in the surface six inches had been displaced. Sodium moved gradually through the profile and the action of a given six-inch addition of water was to move sodium only a short distance

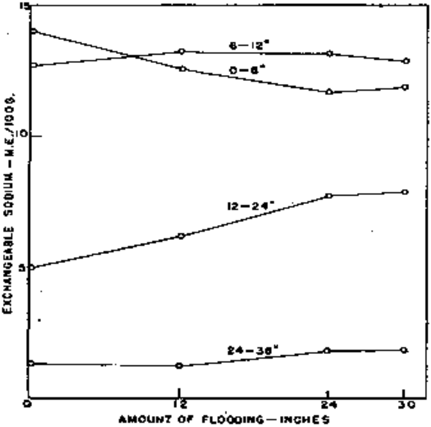

Figure 2.—Exchangeable sodium of four soil layers as affected by leaching (averages of four plots).

downward, where it was readsorbed in a zone of lower exchangeable-sodium-percentage. Thus the initial 12 inches of flooding, which reduced the exchangeable sodium in the surface six inches substantially, caused a marked increase in exchangeable sodium in the six-24 inch layer; and even after 24 inches of flooding, little, if any, sodium had been removed from the upper 36 inches of soil. Had the leaching operations been continued, sodium would eventually be moved beyond the 36-inch depth, but leaching efficiency in the surface layer would undoubtedly decrease as the soil reached a lower exchangeable-sodium-percentage. This is indicated by the leveling off of the curves in Figure 2.

Effect of Gypsum and Furrow Irrigation.—The soluble salt content of the surface layer of all plots increased during the cropping phase of 1950 (Figure 3). Those plots which had been leached in 1949 returned to a saline condition. Where gypsum had not been applied the increase was almost entirely in the surface six inches and reflected the normal upward movement of salts during the summer months. The gypsum-treated plots, however, increased in soluble salts throughout the three-foot sampling depth as a result of the sodium sulfate formed as a product of the reaction between calcium sulfate and the exchangeable sodium.

Gypsum caused a substantial decrease in soil pH (from 10.10 to 8.70 on gypsum plots and from 9.53 to 8.47 on leaching-plus-gypsum plots) in the surface six inches but had very little effect below that depth. **In** con-

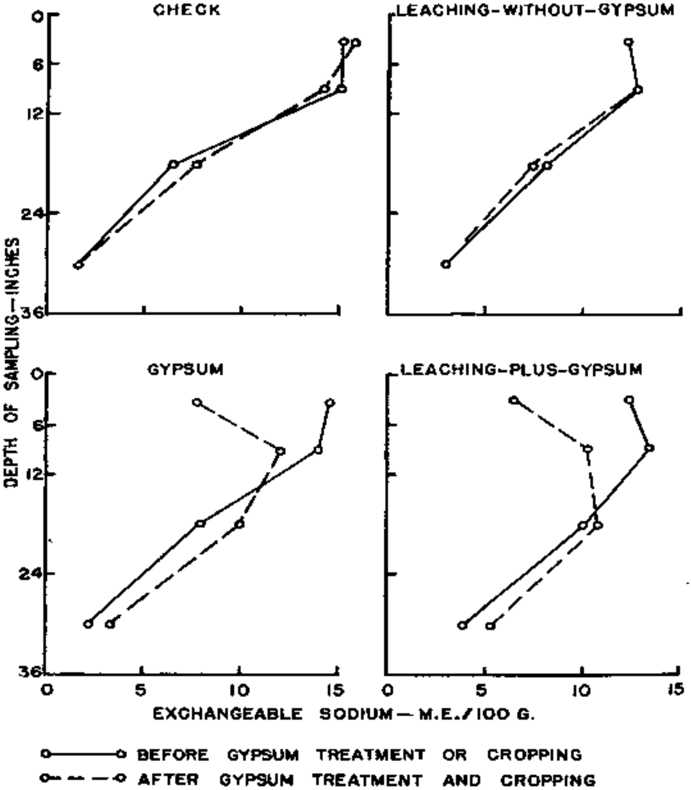

Figure 3.—Salt distribution at the beginning and finish of the cropping season (averages of four plots).

trast, over the same period, no pH change occurred in the plots where gypsum had not been applied.

On all gypsum-treated plots the exchangeable sodium content of the soil decreased (Figure 4), markedly in the surface six inches and to a smaller but significant extent in the six-12 inch layer. These decreases in

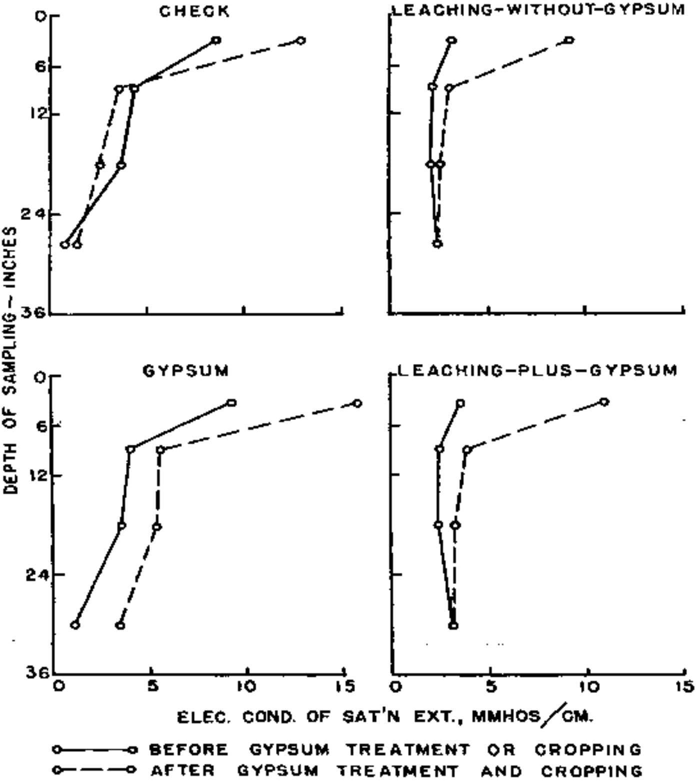

Figure 4.—Distribution of exchangeable sodium at the beginning and finish of the cropping season (averages of four plots).

the zero-six and six-12 inch layers were accompanied in every case by increases in the 12-24 and 24-36 inch depths. Thus the changes in exchangeable sodium were primarily redistribution within the upper three feet of soil and transformation from exchangeable to soluble forms. Data obtained during the study indicate that little if any of the sodium originally in the exchangeable form was moved below the three-foot depth. In comparison, there was no measurable change in the content of exchangeable sodium in any plots which did not receive gypsum (Figure 4) .

The Effect of Leaching and Gypsum Treatments Upon the Stand and Yield of Sugar Beets

Table 1 gives the average stand counts and yield of beets as affected by the various treatments. Seedling emergence was greatly enhanced by

Table 1.—The Effect of Leaching and Gypsum Treatments upon the Stand and Yield of Sugar Beets[1]

Treatment	Beet Plants per 100 Ft. of Row			Yield Tons/Acre
	Before Thinning	After Thinning	Harvested	
No Treatment	222 ± 176	11 ± 5	1	Negligible
Leaching Without Gypsum	527 ± 186	51 ± 7	10 ± 3	Negligible
Gypsum	1009 ± 213	116 ± 9	98 ± 10	10.7 ± 1.2
Leaching Plus Gypsum	935 ± 29	113 ± 2	115 ± 2	18.0 ± 2.8

[1]Averages of four plots. The number following the + is the standard deviation of the mean. Actual counts before and after thinning were on 144 feet of row. The count at harvest time was on 168 feet of row. Only beets over two inches in diameter are considered here.

the presence of gypsum, either with or without previous leaching, to the extent that plots with gypsum had approximately twice as many plants before thinning as did those with leaching only. Although the emergence of beets on plots receiving leaching but no gypsum was comparable to that on gypsum-treated plots, the soil condition was such that many of the plants had died by thinning time (Table 1) and only a few beets reached maturity. Gypsum not only increased the number of seedlings but also increased the vigor of the plants, with the result that wherever gypsum had been applied a good stand of beets remained until harvest.

Essentially no beets were harvested from plots not treated with gypsum, whereas all of the plots which had gypsum produced significant tonnages of beets. Of the two treatments which received gypsum, leaching-plus-gypsum was far superior to gypsum alone, the average yield of marketable beets for the two treatments being 18.0 tons per acre and 10.7 tons per acre respectively. This difference in yield was caused primarily by a difference in beet size rather than number. The weight of individual beets from the gypsum plots averaged only one and twelve one-hundredths pounds as compared with one and forty one-hundredths for the leaching-plus-gypsum treatment. As a consequence of their small size, a high percentage of the beets from the gypsum-treated plots were considered unmarketable (less than two inches in diameter) . Figure 5 illustrates the marked effects of gypsum on the growth of sugar beets.

This study would indicate that leaching this soil without use of a chemical amendment, applied either before or after leaching, would be an undesirable practice for the farmer to follow. Not only would the removal of exchangeable sodium be extremely slow, but also the soil dispersion which occurs following the removal of soluble salts would leave the soil too puddled for plants to grow. The factors limiting seed germination, seedling emergence, and subsequent growth of plants on saline-alkali soils are complex, as are the effects of gypsum in overcoming them. Both chemical and physical factors are involved. Gypsum may function in several ways. It provides calcium ions for the replacement of exchangeable sodium and for the formation of a more desirable calcium-sodium ratio in the soil, and reduces the dispersion and puddling which is usually associated with alkali soils.

Figure 5.—A view of a portion of the experimental field at harvest time: A. Leaching-plus-Gypsum, B. No Treatment, C. Gypsum alone, D. Leacbing-without-Gypsum.

Summary and Conclusions

The effects of leaching and gypsum treatments on the reclamation of an unproductive saline-alkali soil (Umapine fine sandy loam) in the Yakima Valley of Washington were followed by periodic soil analysis and by measuring yields of sugar beets. The results can be summarized as follows:

1. The productivity of this saline-alkali soil can be raised from virtually nothing to reasonable levels by treatment with large quantities of gypsum. A satisfactory germination was observed on the check and leached plots but the beet seedlings failed to survive and no beets were harvested. On all gypsum-treated plots full stands of mature beets were obtained. The difference between the 10.7 tons per acre of beets obtained from plots treated with gypsum alone and the 18.0 tons per acre obtained from plots leached prior to treatment with gypsum was due to a greater average beet weight on the leached plots and is attributable to the removal of excess salinity by leaching.

2. Leaching without gypsum will effect some removal of exchangeable sodium but the rate of removal is too slow to be of practical significance. Once the soil salinity is reduced, penetration of water becomes extremely slow and an undesirable puddled surface structure develops.

3. Xhe presence of gypsum greatly accelerates the removal of exchangeable sodium. Although plots leached prior to treatment with gypsum produced greater tonnages of beets than did those receiving only gypsum, their exchangeable sodium status at the end of the growing season was not substantially different. Xhe beneficial effect of leaching on the yield of beets is due to removal of excess salinity. Treatment with gypsum followed by normal irrigation is far more effective in removing exchangeable sodium than is leaching through diked plots without gypsum.

4. Although the leaching and gypsum treatments greatly improved the soil condition and permitted a satisfactory crop of beets to be grown on certain plots, they did not fully reclaim the soil during the course of a single crop year. As the exchangeable sodium in the surface soil is reduced, there is an increase in exchangeable sodium in the subsoil. Removal of exchangeable sodium from the entire root zone is a slow process.

Literature Cited

(1) BOAWN, Lours C.
1951. Reclamation of a saline-alkali soil by leaching and gypsum treatments. Unpublished Master's thesis, Xhe State College of Washington, Pullman, Washington.

(2) HEALD, WALTER R., MOODIE, C. D., and LEAMER, ROSS W.
1950. Xhe production of sugar beets on a saline soil as affected by the type of leaching; with special reference to the value of pre-emergence irrigation. Proc. Am. Soc. Sugar Beet Xech. 1950 pp. 448-452. Cf also Leaching and pre-emergence irrigation for sugar beets on saline soils. Washington Agr. Exp. Sta. Bul. No. 519.