Effect of Saline and Alkali Soil on Growth of Sugar Beets

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The relatively high salt tolerance of sugar beets during the later stages of growth is well known. Although this characteristic is sometimes designated as "alkali" tolerance, in most instances the soil condition under reference is characterized by salinity rather than a high level of exchangeable sodium. It appeared expedient to test the tolerance of sugar beets to salinity and to alkali, per se, on field plots especially prepared to effect uniformity of salinization or alkalization. Eight 10 foot x 10 foot plots were set up according to procedures described by Wadleigh and Eireman (3) .[2]

The year previous to the cropping season, four of the plots had been leached with a heavy application of sodium bicarbonate solution so that the resulting exchangeable sodium percentage in the surface foot of soil averaged about 50. The other four plots contained untreated Pachappa fine sandy loam. In each plot four 10-inch beds were prepared so as to be 30 inches apart on center and 5 inches high. On February 18, 1949, two of the beds in each plot were planted to a single row of U. S. 22, and the other two beds were planted with seeds of a selection made by Bion Tolman of the Utah-Idaho Sugar Co. from outstandingly tolerant beets in a field of U. S. 22 seriously afflicted with salinity and located in the Yakima Valley, Washington.

Two plots with normal soil and two with alkali soil were irrigated with Riverside water throughout the season. The former treatment was designated as the "control," and the latter was designated as the "alkali" treatment. The other four plots received irrigation water fortified with NaCl to the extent of 3,000 to 12,000 ppm., the concentration being increased with the advance of the season. Thus, the previously untreated soil receiving saline irrigation water was designated as the "saline" treatment, and the plots which had received the preliminary sodium bicarbonate treatment together with saline irrigation water were designated as the "saline-alkali" treatment.

Nutrient requirements were supplied in the irrigation water. During the forepart of the season, each application of water was fortified with 400 ppm. of metaphosphate and 200 ppm. of KNO_3. Nutrient application was discontinued during July.

Table 1 shows the status of salinity and alkali in the soil samples taken from the centers of the rows at the end of the growing season September 28, 1949. It is to be noted that the sodium bicarbonate treatment resulted in a rather high pH of this soil, and also a rather high exchangeable sodium percentage (ESP) . Since the initial ESP averaged about 50, the data for this entity from the alkali plots actually showed that exchangeable sodium

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[2] Numbers in parentheses refer to literature cited.

in the soil had decreased during the course of the season, presumably from the effect of the soluble calcium *in* the Riverside irrigation water applied. The saline soil showed very high electrical conductivities of the soil extract, relatively low pH values, and very high ESP values. The application of neutral salt, sodium chloride, effected a replacement of calcium from the exchange complex, but the high concentration of salt in the soil solution tended to maintain a nearly neutral reaction. The saline-alkali soil had electrical conductivity and ESP values similar to that of the saline soil, but the pH of the soil extract was much higher.

During the course of the experiment, tensiometers were maintained in the rows and furrows of plots subjected to the various treatments. Water was applied to all plots when the tensiometers *in* the "control" plots installed at the 8-inch depth showed 400-500 cms. of tension. In the alkali plots, however, the tensiometers were almost continuously off-scale, even

Table 1.—Evaluation of Salinity and Alkali Status of Soil Samples Taken from Centers of Rows on September 28, 1949.

Treatment	Soil stratum	pH of 1:1 extract	EC_e[1]	Exchangeable sodium in soil	
	Inches		Millimhos/cm.	me./100 gms.	Percent[2]
Control	1-9	8.2	0.81	0.05	0.6
	9-18	8.0	.51	.08	1.0
	18-27	7.9	.72	.03	0.4
Alkali	1-9	9.3	3.21	3.01	37.6
	9-18	9.1	1.05	1.90	23.9
	18-27	8.6	.78	.74	9.2
Saline	1-9	7.5	18.0	6.18	77.2
	9-18	7.2	14.4	5.06	63.2
	18-27	7.5	10.5	4.30	53.8
Saline-alkali	1-9	8.6	27.3	7.15	89.4
	9-18	8.4	17.7	4.57	57.1
	18-27	8.1	14.7	3.72	46.5

[1] Electrical conductivity of extract of saturated soil calculated from ECi (2).

[2] Based on an exchange capacity of 8 me./100 gms.

when water had been standing in the furrows several days. On irrigating with 1 1/2 inches of water, the water would infiltrate the soil of the control plots in four to five hours' time, but it would stand in the furrows of the alkali plots for several days. It is possible, consequently, that a major fraction of each application of water on the alkali plots was lost through evaporation, and never entered the soil. This effect of high ESP value on the infiltration of water into such soil is typical. Little difficulty was encountered with the infiltration of water on the saline and saline-alkali plots. In these instances the irrigation water contained sufficient electrolyte to counteract the dispersing tendency of the high exchangeable sodium found in the soil of these plots. Although infiltration of water was slower than in the case of the control plots, it would usually disappear from the furrows within 12 hours after a 1 1/2 inch irrigation.

The beets were harvested September 30, 1949. Table 2 presents the leverage yield of beets from the plots, together with the sucrose percentages of the roots and the mineral content of the foliage. Since there was virtually no difference between the performance of variety U. S. 22 and Tolman's selection therefrom, observations on the two varieties are averaged in the data of Table 2. The only exception occurred on the saline plots. Under this treatment the Tolman selection produced 15 percent more beets than the ordinary strain of U. S. 22. The difference in yield was significant and suggested that a small advance in salt tolerance was made through selection.

It is evident from Table 2 that the alkali soil containing all the necessary nutrient elements and adequate water as far as application was concerned, resulted in a markedly lower yield. The authors believe that this lower yield was a result of inadequate infiltration of water together with impaired movement down to the roots. Actually, on every hot day during the summer the beets on the alkali plots would be seriously wilted, whereas those on the control plots would be turgid. That is, the difference in yield between the two treatments might well be interpreted as the accrued effect of the difference in soil moisture stress prevailing on the roots under these two conditions during the course of the growing season. The presence of salinity in the irrigation water was associated with relatively low yields in comparison with those observed on the control plots. However, the growth of the beets on these plots was sufficient to correspond to a yield of 30 tons per acre. Since the soil samples from these plots showed EC_e values of 10-20 millimhos/cm. during the major part of the growing season, the high salt tolerance of sugar beets is evident. Most crop plants cannot survive under this level of salinization (2).

Table 2.—Yield, Sucrose Content and Mineral Composition of Beets.

Treatment	Yield[1] lbs./10 foot row	Sucrose content Percent	Cationic content of leaves and petioles Na	K	Ca	Mg
				me. per 100 gms. dry wt.		
Control	69.0	13.4	160	136	44	46
Alkali	51.7	13.9	270	80	36	48
Saline	38.9	14.3	336	81	44	55
Saline-alkali	33.5	12.6	369	65	43	58
L.S.D. (.05)	4.6	1.4				

[1] To convert to T/A, multiply by 0.87.

The sucrose content of all beets at the time of harvest was low, and variation among treatments was not sufficient to warrant comment.

Sugar beet foliage produced on the various treatments showed remarkably little variation in content of calcium and magnesium, but an enormous variation in sodium content and an appreciable variation in potassium. The beets grown under the control treatment actually accumulated 160 me. of sodium per 100 grams of dry tissue. Sodium in the foliage of most species of plants under this treatment would be comparatively low. Inducing exchangeable sodium into the soil almost doubled the sodium content of the leaves, and under the imposed salinization the sodium content of the foliage was more than double that from the control plots. Associated with the variations in sodium content, there tended to be an inverse level of accumulation of potassium; that is, the potassium content of the foliage was at the highest in the control plants and tended to be lower in foliage with the higher sodium content.

In some species of plants, beans for example, variations in the calcium content of the tissue is a good index of the degree to which these plants have been subjected to increasing levels of exchangeable sodium in the growing medium (1) . On the basis of the evidence herein presented, calcium content of sugar beet leaves would not be a good index of such soil conditions. On the other hand, even though the sugar beet plant readily accumulates very high levels of sodium in the leaves, it is quite possible that, if the level of accumulation exceeds 200 me. per hundred grams of leaf tissue, the plants may be subjected to adverse levels of salinity and exchangeable sodium *in* the soil.

Summary

Half of the experimental plots used for this study were set up on the normal soil prevailing on the grounds of the Salinity Laboratory. The remaining plots had been leached the previous year with a heavy application of sodium bicarbonate solution, so that the exchangeable sodium percentage of the upper two feet of soil averaged about 50. Half of the plots on each of the two soil conditions were then irrigated with normal irrigation water, and the other half of the plots received irrigation water which had been fortified with NaCl to the extent of 3,000-12,000 ppm., the concentration being increased with the advance of the season.

Serious difficulty was encountered in obtaining water penetration on the alkali plots. Following irrigation, water Would stand in the furrows for days at a time; consequently, the plants in these plots would wilt seriously on days conducive to a high rate of transpiration. In view of the frequency with which beet plants in the alkali plots showed moisture stress, the yields were surprisingly good.

Even though the imposed level of salinization was high and effected a 50 percent reduction in yield, the beets on these plots made surprisingly good growth.

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