The Production of Sugar Beets on a Saline Soil as Affected by the Type of Leaching[1,2]

WITH SPECIAL REFERENCE TO THE VALUE OF PRE EMERGENCE IRRIGATION

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INTRODUCTION

Saline soils are numerous in the lower Yakima valley in south central Washington. The areas in which salts have accumulated in quantities detrimental to plant growth vary in size from spots of several square yards to whole fields. The sugar beet, because of its high salt tolerance, once it is established, is the principal crop grown in these saline soils.

The failure to obtain profitable yields of sugar beets on saline soils is due to failure to obtain satisfactory stands, and to reduction in growth of the beets once a stand is established. This report is concerned with the effects upon the stand and yield of beets of leaching a saline soil during the winter to lower the salt concentration in the root zone, and of irrigation in rills adjacent to the beet row during the period of germination to lower the salt concentration in the viginity of the germinating beet seed. Since the rill irrigations adjacent to the beet row were applied during the germination period and before the beets emerged, this type of irrigation is referred to as pre-emergence irrigation.

PROCEDURE

Plots were established on Esquatzel loam in a 6-acre field near the town of Sunnyside, Washington. Although the soil in this particular field is saline-alkali it contains 1 to 2 per cent of gypsum; and in behavior it is representative of many of the saline soils under crop in this region. Typically, the salt content of the soil is variable from place to place and with depth, but ranges from 2,000 to 10,000 p.p.m. ($EC \times 10^3 = 3$ to 15^1).

Water was applied during the winter in two general ways: by furrow irrigation at two rates, and by flooding at 4 rates. Pre-emergence irrigation

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[2] This report is concerned with a portion of the work carried out under a Memorandum of Agreement among the Utah-Idaho Sugar Company, the Washington Agricultural Experiment Stations, and the Bureau of Plant Industry, Soils, and Agricultural Engineering.

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was applied appropriately for 8-hour periods at weekly intervals; 0, 1, or 3 irrigations to the plots in the furrow irrigation series, and 0 or 3 irrigations to plots in the flooded series. Each plot within the furrow irrigation series was split for seed rate; 3 or 7 pounds of segmented seed.

Following winter leaching, the field was leveled and a uniform placement of 80 pounds of N and 110 pounds of P_2O^5 per acre was made over the entire field in bands 3 inches deep and 11 inches apart at right angles to the furrows.

All plots were planted with segmented seed of the variety of U. S. 22 on March 30 and 31, 1948. The furrows for pre-emergence irrigation were opened within 2 to 3 inches of the beet row by means of special disks attached to the frame of the 6-row drill used for planting. When the beets were thinned, new furrows for normal irrigation were made in the center between the rows.

Following the winter leaching treatments and pre-emergence irrigation, all field operations were those used by farmers. The beets were pulled, topped, counted, and weighed on November 16 and 17, 1948. Only beets more than 2 inches in diameter were counted and weighed.

A measure of the concentration of salts in each plot following winter leaching was obtained by determining the electrical conductivity of 1:1 soil: water extracts. These data are not presented here.

All the data have been averaged. Although the rate of seeding had some small influence upon the stand of beets after thinning, it had no significant effect upon the number of marketable beets[4]. The number of beets per 100 feet of row, and the yield of beets in tons per acre, are reported in Tables **1** and 2.

RESULTS AND DISCUSSION

The Effect of Pre-emergence Irrigation on the Stand and Yield of Beets

Pre-emergence irrigation has the effect of moving salts laterally out of the beet row, thereby improving germination and emergence. The stand is improved whenever pre-emergence irrigation is applied, but the greatest improvement is apparent in plots from which no salt was removed by winter leaching. Up to a certain point, the yield of beets is a function of the density of stand. Three pre-emergence irrigations applied to plots receiving no winter leaching increased the stand of beets from 20-30 beets per 100 feet of row to 80 beets per 100 feet of row, and increased the yield from 4 to 11 tons in one experiment (Table 1) and from 8 to 20 tons in another (Table 2) . However, stand density is not the sole reason for increased yield. Above a certain stand density (approximately 70 to 80 beets per 100 feet of row in this study) , the yield is determined principally by factors other than stand since significant increases in the numbers of beets resulting from pre-emergence irrigation are not accompanied by significant increases in yield.

Placement of furrows for pre-ernergnce irrigation is fundamentally different from that of furrows for normal irrigation. The normal consequence of water moving from a furrow into saline soil is the movement of salts

[4] The measurement of salt concentration in this study was in terms of electrical conductivity of the 1:1 soil: water extract expressed as millimhos per cm. ($E\ C\ x10^5$). The approximate expression in p.p.m. is obtained by multiplying the electrical conductivity x 700. The relationship of the conductivity of the 1:1 extract ($EC_{1:1}$) to that of the saturation extract (ECc) is expressed in the equation $ECc = -2.3 + 2\ EC_{1:1}$.

laterally and vertically away from the furrow. In the case of pre-emergence irrigation, the salts are moved laterally *past* the beet seed which can then germinate and emerge from a soil zone relatively low in salts. In contrast, normal irrigation moves salts effectively *into* the beet row. Thus, it is apparent that the placement of the furrow for pre-emergence irrigation must be as close as possible to the seed, if it is to be effective. Irrigation in the usual manner would have the opposite effect.

Table 1. The Number and Yield of Marketable Sugar Beets as Affected by Winter Leaching (Furrow Irrigation) and Pre-emergence Irrigation.

Winter treatment	Number of pre-emergence irrigations 0	1	3
	Average Number of Beets in 100 ft. of row*		
None	26.9 ± 5.9+	68.9 ± 3.7	81.8 ± 2.5
Leached by furrow irrigation**	74.1 ± 5.6	82.3 ± 4.1	91.3 ± 3.9
	Average Yield of Beets in T/A***		
None	7.9 ± 2.0	17.1 ± 1.2	20.4 ± 1.1
Leached by furrow irrigation**	20.5 ± 2.2	22.2 ± 1.2	24.4 ± 1.6

*Based upon the number of marketable beets in 160 feet of row; averages for 12 plots.
**A total of 6 to 8 acre inches was applied.
***Based on the net weight of beets in 160 feet of row; averages for 12 plots.
+The value following the ± is the standard deviation of the average yield.

Inasmuch as little extra effort is involved in applying pre-emergence irrigation, the increases in yield shown, 12 tons in one case (Table 1) and 7 tons in another (Table 2), represent a substantial and significant gain to the beet grower.

The Effect of Winter Leaching on the Stand and Yield of Sugar Beets

The data presented in Tables 1 and 2 show the value of winter leaching, and consequently of salt removal, in improving the productivity of saline soils. Data obtained (1), but not presented here, show that, in general, the stand and yield of beets is proportional to the concentration of salts in the region of the growing plants. A stand can be established by reducing temporarily the salt concentration for the young beet plant by means of pre-emergence irrigation. However, with the beginning of normal irrigation (which follows thinning) this more favorable environment for the beet is lost, and for the greater part of its life the beet must grow in highly saline soil. Thus, after a stand of beets has been established by a saline soil by pre-emergence irrigation, the yield of beets is still affected and finally determined principally by the salt concentration.

Winter leaching with 6 to 8 inches of water by furrow irrigation reduced the salt content in the first foot of soil, but did not materially change it below that depth (1). The effect of this relatively minor removal of salt was to increase the yield of beets by approximately 12 tons on plots receiving no other treatment, and by 4 to 5 tons when a stand was established by pre-emergence irrigation (Table 1).

Winter leaching by flooding was highly effective in removing excess salt from the soil. The extent of removal was proportional to the amount of water used. Twenty-four inches of water reduced the salt content by 50

per cent throughout the first 3 feet of soil (1). The extensive salt removal by flooding increased the stand of beets by 100 to 500 per cent. It increased the yield by 21 tons per acre for 12 inches of water, and by 28 tons for 24 inches of water on plots receiving no other treatment.

It may be concluded, then, that pre-emergence irrigation is effective in establishing a stand of beets on saline soils. This practice should be highly profitable to the beet grower, since the establishment of a stand guarantees a yield of beets not otherwise obtainable. The ultimate goal,

Table 2. The Number and Yield of Marketable Sugar Beets as Affected by Winter Leaching (Flooding) and Pre-emergence Irrigation.

Winter treatment	Number of pre-emergence irrigations	
	0	3
	Average Number of Beets in 100 feet of row*	
None	22.0 ± 5.8+	83.0 ± 2.7
Flooded (12 inches)	87.3 ± 2.7	99.3 ± 3.5
Flooded (17 inches)	94.3 ± 3.2	104.8 ± 5.5
Flooded (24 inches)	98.3 ± 4.0	105.5 ± 2.5
	Average Yield of Beets in T/A**	
None	4.1 ± 1.2	11.0 ± 1.1
Flooded (12 inches)	24.7 ± 1.7	26.7 ± 0.9
Flooded (17 inches)	29.7 ± 1.5	27.7 ± 2.6++
Flooded (24 inches)	32.4 ± 1.1	29.5 ± 1.7

*Based upon the number of beets in 180 feet of row. Averages for 4 plots.
**Based upon the weight of beets in 80 feet of row. Averages for 4 plots.
+The value following the ± is the standard deviation of the average yield.
++This value includes only 3 plots.

however, must be to remove permanently the major part of the excess salts, since it is only thus that good yields of all crops can be obtaind.

CONCLUSIONS

The principal conclusions to be drawn from this study of the effect of the type of leaching upon the production of sugar beets on a saline soil can be summarized as follows:

1. *Failure to produce profitable yields of sugar beets on saline soils is due principally to two factors: failure to obtain a full stand of beets, and reduced, groivth of the beets once a stand is established.*

2. The application of irrigation water in standard furrows causes salts to move laterally and verically axvay from the furrow and to accumulate in and on the ridges and around the sugar beets.

3. *Removal of harmful salt can be accomplished by leaching, provided drainage can be established.* Leaching to remove salts is carried out most effectively by flooding but can be carried out slowly by applying water in furrows during the non-growing season or by *over-irrigation* during the growing season.

4. *The removal of salts is beneficial for both germination and emergence of the beets and for their subsequent groivth.* The benefit is most pronounced in the improvement in stand, because the period of germination and emergence of the sugar beet is the most critical in its development in saline soil. Once the young beet is established, it is appreciably salt-tolerant.

5. *Irrigating after planting in special furrows placed close to the beet row brings about a temporary reduction in salt conceneration in the vicinity of the germinating beet seed, thereby substantially improving the germination and emergence.* This practice, termed pre-emergence irrigation, makes it possible to establish fair to good stands even in highly saline soil when little or no stands can be established by the usual practices. At thinning time, these special furrows are abandoned and new furrows are made between the rows.

6. *Stands were increased from 20 or 30 beets to 70 beets per 100 feet of row with 1 pre-emergence irrigation, and to 80 beets per 100 feet of row with 3 pre-emergence irrigations in plots from which no salt had been removed by winter leaching. This increase in stand resulted in increases in yield from 8 to 20 tons in one series of plots and from 4 to 11 tons in another.*

7. *Above a certain stand density (approximately 70 to 80 beets per 100 feet of row), the yield is determined by factors other than stand, principally salt concentration; because, once a stand is established, the yield increase is roughly proportional to the decrease in salt.*

8. *For maximum yields, it is necessary to remove salts by leaching. Thus xvhere pre-emergence irrigation increased yields from 4 to 11 tons per acre on plots not winter leached, flooding with 12, 17, and 24 inches of water increased the yields of beets from 4 to 25, 30, and 32 tons per acre respectively.*

9. *Pre-emergence irrigation probably should not be applied to soils which crust over seriously by drying. Crusting may effectively prevent emergence of the beet seedlings.*

10. *Pie-emergence irrigation is a valuable practice which should enable the grower to establish a stand of beets on a saline soil and thus obtain some yield on otherwise waste land. If at the same time sufficient water is applied to remove salt from the field, a permanent and profitable reclamation is possible. It should be emphasized that it is necessary to establish drainage before a permanent reclamation can be effected.*

Literature Cited

1. HEALD, WALTER R. 1949
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