EXPERIMENTS IN WATERING SUGAR BEETS IN WESTERN NEBRASKA

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Experiments, utilizing small, replicated plots, have been conducted near Scottsbluff, Nebr., over a 4-year period for the purpose of comparing results from watering sugar beets at different application rates and with the timing of applications of irrigation water in accordance with the soil moisture situation rather than at fixed time intervals. In this and many other irrigated areas, water is less plentiful than land. It has been found that certain methods of applying irrigation water to the land produce better yields per acre than others, and furthermore, that much better returns are obtained by some methods of water use than by others. In the first 3 years of experimentation the highest sugar-beet yields were obtained by the use of high and medium amounts of water per acre and the best returns per unit of water were obtained by the use of low and medium amounts of water per acre. The two curves, which slope in opposite directions, indicated that, by the proper adjustment of the use of land with the use of water, a considerable improvement would be possible in the irrigation of sugar beets. Results from a fourth year of trial are now available, permitting further analysis and conclusions. Such a study conducted a few years in one locality covers only part of the broad problem but does provide suggestions for better irrigation practices for other irrigated areas.

The total inches of water used by the crop in these experiments, includes the moisture in the soil at the time the crop was planted plus rainfall and irrigation water applied less the water lost from surface evaporation, percolation, and less the moisture remaining in the soil at harvest time. However, this paper is written on the basis of the requirements of irrigation water to grow a successful crop and not on the basis of total use of water by the crop. Climatic variations cause the sugar-beet plots to use twice as much of the available soil moisture during some periods of one day, one week, one month, or one season as during the preceding or following similar period of time. The common practice, on too many beet fields, is to irrigate at definite intervals of time and to use relatively equal and large amounts of water at each irrigation. In these tests, a quick method was used for the determination of the available soil moisture content, and these readings determined when water was to be applied. The indications from these experiments are that irrigation practices on farms could be improved by appropriate adjustment in the amount of water applied at a given irrigation period and by use of improved methods for determining when irrigation is needed.

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Experimental Methods

There were nine treatments with four replications of each treatment. The treatments fall into interrelated series as to the rates of water application and situation as to soil moisture when the various applications are made. Twelve plots were irrigated with 3 inches of water per application, 12 plots received 4½ inch applications, and 12 plots - 6-inch applications. The differential rates of watering were subdivided so that four plots for each application rate were irrigated when the soil still contained a high moisture content (50 percent, approximately, of total of the available moisture still present), four were irrigated when approximately 75 percent of the available moisture had been used, and four received irrigation water only when the soil began to approach the wilting point.

Plaster of paris blocks (1) to permit the readings of estimation of soil moisture by the electric resistance method were placed in the ground at depths of 6, 12, 24, and 36 inches, which made possible a study of the distribution of the water in the soil to the depth of 36 inches. The reading of the block at the 12-inch depth was the one most often used to determine time at which the appropriate irrigation should be applied to a plot.

The fields, for these tests, were selected because of convenient location to an adequate supply of water so that irrigation could be applied whenever desired. Relatively flat land was used so that the water could be applied equally to all parts of the plot by gravity flow of the water in the furrows between the rows. Each field was laid off in small plots; in 1940 and 1941, 12 rows of beets 20 inches apart and 66 feet long constituted a plot; in 1942 and 1943, 20 rows, 35 feet long, were used. The approximately square plots used in 1942 and 1943 provided somewhat better distribution of water than the longer and narrower plots of the previous years. A dike was made between plots by destroying pairs of beet rows. In this 40-inch wide path, the dikes were built to a height of 6 inches to prevent run-off of waste water. The irrigation water was conveyed to the plots by the use of metal or wood flumes equipped with outlets that could be set to regulate the flow of water to each row of beets. Calculation of the amount of water used was made by use of Parshall flumes and by measurement in gallons of water of the flow per minute from the outlet into the beet furrow. The fields selected were of high fertility and had produced approximately 20 tons of beets per acre if properly irrigated. This high yield is an indicator that there is no serious alkalinity problem. Borings were made to a depth of 7 feet and kept open during the growing season so that it was possible to determine that there was no water table in the soil at this depth.

(1) More detailed explanation of methods are included in previous publications. Nuckols, S. B., Moisture Requirements for Sugar Beets, 48th annual report, Nebraska State Irrigation Association, Dec., 1940.

(1) Nuckols, S. B., Studies of Moisture Requirements of Sugar Beets, American Society of Sugar-Beet Technologists, 1942, Proceedings.

Discussion

To all plots of sugar beets grown during the 4 years of tests, the mean application of water was 12.91 acre-inches. The mean yield of sugar beets from all of these plots was 21.17 tons of roots with 16.59 percent sucrose content, corresponding to 3.507 tons of gross sugar per acre. Each acre-inch of water applied to these plots produced, as an average, 0.294 tons of gross sugar per acre.

From all plots receiving 3 acre-inches of water per application, the mean yield of sugar-beet roots was 21.02 tons per acre with a sucrose content of 16.58 percent. 3.471 tons of gross sugar were produced per acre. For each acre-inch of water applied there was produced, as an average, 0.377 tons of gross sugar per acre. The mean application of water was 9.47 acre-inches.

All plots receiving 4½ acre-inches of water per application had a mean acre-yield of sugar-beet roots of 21.15 tons with a sucrose content of 16.65 percent. 3.521 tons of gross sugar were produced per acre. For each acre-inch of water applied there was produced 0.277 tons of gross sugar per acre. The mean application of water to these plots was 13.30 acre-inches.

From all plots receiving 6 acre-inches of water per application, the mean yield of sugar-beet roots was 21.33 tons per acre with a sucrose content of 16.54 percent. 3.528 tons of gross sugar were produced per acre. For each acre-inch of water applied there was produced 0.227 tons of gross sugar per acre. The mean application of water to these plots was 15.97 acre-inches.

To all plots which were irrigated when approximately 100 percent of the available soil moisture in the top foot had been used, there was applied, as an average, 9.82 acre-inches of water. The mean yield of sugar-beet roots from this group of plots was 20.44 tons per acre with a sucrose content of 16.46 percent. 3.367 tons of gross sugar were produced per acre. Each acre-inch of water applied to these plots produced 0.356 tons of gross sugar per acre.

Plots irrigated when 75 percent of the available soil moisture in the top foot of soil had been used received a mean application of 12.87 acre-inches of water. On these plots, the mean acre-yield of sugar beets was 21.19 tons with a sucrose content of 16.47 percent. 3.488 tons of gross sugar were produced per acre. The mean acre-yield of gross sugar for each acre-inch of water applied to these plots was 0.289 tons.

To all plots which were irrigated when 50 percent of the available soil moisture in the top foot of soil had been used, the mean application of water was 16.07 acre-inches. On these plots the mean yield of sugar-beet roots was 21.87 tons per acre with a sucrose content of 16.84 percent. 3.666 tons of gross sugar were produced per acre. The mean acre-yield of gross sugar for

each acre-inch of water applied to these plots was 0.237 tons.

In consideration of these treatments, it must be remembered that those averaged on basis of acre-inches of water applied per application include the three variations of degrees of exhaustion of available soil moisture previous to irrigation. Likewise, any of the means based upon degree of exhaustion of soil moisture previous to irrigation include each of the 3 rates of application of water per irrigation. Furthermore, the average returns per acre-inch of water applied do not take into account water received from rainfall or any water that may have been in the ground at the beginning of the growing season. This study does not determine the returns per acre-inch of water used by the crop, but is designed to show the returns per acre-inch of irrigation water applied in a series of comparable plots. (Tables 1, 2, 3, 4.)

Table 1.- The acre-inches of water applied in the irrigation experiments conducted at Scottsbluff, Nebraska, in 1940, 1941, 1942, and 1943.

Water Applied					
Approximate moisture at 12-inch level when irrigation was made	years	Application rate in acre-inches 3	4½	6	12-plot averages
percent	years	inches	inches	inches	inches
50	1940	18.00	25.88	28.50	24.13
	1941	10.50	12.38	16.50	13.13
	1942	9.00	13.50	15.00	12.50
	1943	10.20	15.30	18.00	14.50
16-plot averages		11.93	16.77	19.50	16.07*
25	1940	12.75	20.25	22.50	18.50
	1941	6.00	10.33	12.00	9.42
	1942	7.73	11.25	14.00	10.99
	1943	9.00	12.60	15.60	12.40
16-plot averages		8.87	13.61	16.03	12.83
0	1940	11.25	12.38	16.50	13.38
	1941	5.33	6.75	9.00	7.00
	1942	6.00	9.00	12.00	9.00
	1943	7.80	9.90	12.00	9.90
16-plot averages		7.60	9.51	12.38	9.82
Rates of Application Means					
	1940	14.00	19.50	22.50	18.67
	1941	7.25	9.82	12.50	9.86
	1942	7.58	11.25	13.67	10.83
	1943	9.00	12.60	15.20	12.27
		9.46	13.29	15.97	12.91

* Mean for 48 plots

Table 2.- The effect of different applications of irrigation water upon the acre-yield of roots of sugar beets as obtained from experiments conducted at Scottsbluff, Nebraska, in 1940, 1941, 1942, and 1943.

Calculated Acre-Yield of Roots					
Approximate moisture at 12-inch level when irrigation was made	years	Application rate in acre-inches 3	4½	6	12-plot averages
percent	years	tons	tons	tons	tons
50	1940	23.80	24.20	24.40	24.13
	1941	21.53	21.17	21.73	21.47
	1942	20.20	20.75	21.11	20.69
	1943	20.93	21.73	20.87	21.18
16-plot averages		21.62	21.96	22.03	21.87*
25	1940	21.80	21.80	22.70	22.10
	1941	20.70	21.33	20.77	20.93
	1942	20.96	20.77	20.36	20.70
	1943	21.55	20.74	20.75	21.01
16-plot averages		21.25	21.16	21.15	21.19*
0	1940	20.20	20.50	21.40	20.70
	1941	20.38	21.12	21.72	21.07
	1942	19.58	19.07	20.20	19.62
	1943	20.55	20.59	19.96	20.37
16-plot averages		20.18	20.32	20.82	20.44*
Rates of Application Means					
	1940	21.93	22.17	22.83	22.31
	1941	20.87	21.20	21.40	21.16
	1942	20.25	20.20	20.56	20.34
	1943	21.01	21.02	20.53	20.85
* Mean for 48 plots mean for all application rates		21.02	21.15	21.33	21.17

Table 3.- The effect of different applications of irrigation water upon the sucrose content of sugar beets as obtained from experiments conducted at Scottsbluff, Nebraska, in 1940, 1941, 1942, and 1943.

Approximate moisture at 12-inch level when irrigation was made	years	Sucrose Percentage as Determined from Samples: Application rate in acre-inches 3	4½	6	12-plot averages
percent	years	percent	percent	percent	percent
50	1940	16.20	16.80	16.30	16.43
	1941	17.38	17.26	17.30	17.31
	1942	16.00	16.48	16.50	16.33
	1943	17.24	17.00	17.00	17.08
16-plot averages		16.71	16.89	16.78	16.84*
25	1940	15.00	15.40	15.70	15.37
	1941	17.38	17.20	17.10	17.22
	1942	16.45	16.88	16.23	16.52
	1943	16.78	16.94	16.52	16.75
16-plot averages		16.40	16.61	16.39	16.47*
0	1940	15.00	15.50	15.30	15.27
	1941	17.50	17.53	17.48	17.50
	1942	16.20	16.35	16.35	16.30
	1943	17.16	16.40	16.68	16.75
16-plot averages		16.47	16.45	16.45	16.46*
Rates of Application Means					
	1940	15.40	15.90	15.77	15.69
	1941	17.42	17.33	17.29	17.35
	1942	16.42	16.57	16.36	16.45
	1943	17.06	16.78	16.73	16.86
		16.58	16.65	16.54	16.59

* Mean for 48 plots

Table 4.- The effect of different applications of irrigation water upon the gross sugar acre-yield of sugar beets as obtained from experiments conducted at Scottsbluff, Nebraska, in 1940, 1941, 1942, 1943.

Approximate moisture at 12-inch level when irrigation was made	years	Calculated Acre-yield of Gross Sugar Application rate in acre-inches 3	4½	6	12-plot averages
percent	years	tons	tons	tons	tons
50	1940	3.843	4.061	3.968	3.957
	1941	3.734	3.655	3.756	3.715
	1942	3.227	3.419	3.484	3.377
	1943	3.610	3.681	3.554	3.615
16-plot averages		3.604	3.704	3.691	3.666*
25	1940	3.295	3.364	3.581	3.413
	1941	3.595	3.667	3.548	3.603
	1942	3.442	3.499	3.304	3.415
	1943	3.617	3.517	3.431	3.522
16-plot averages		3.487	3.512	3.466	3.488*
0	1940	3.019	3.187	3.284	3.163
	1941	3.571	3.701	3.791	3.687
	1942	3.172	3.125	3.306	3.201
	1943	3.529	3.379	3.333	3.414
16-plot averages		3.323	3.348	3.429	3.366*
	Rates of Application Means				
	1940	3.386	3.537	3.611	3.511
	1941	3.633	3.674	3.698	3.668
	1942	3.280	3.348	3.365	3.331
	1943	3.585	3.526	3.439	3.517
		3.471	3.521	3.528	3.507

* Means for 48 plots

Table 5.- Sugar beet yields from irrigation experiment at Scottsbluff, Nebraska, summary of 1940, 1941, 1942, and 1943, in which irrigation water was applied at different ratns, and at different levels of exhaustion of available soil moisture.

Approximate moisture at 12-inch level when irrigation was made	Water Applied: Application rate in acre-inches 3	4½	6	48-plot averages
percent	inches	inches	inches	inches
50	11.93	16.77	19.50	16.07
25	8.87	13,61	16.03	12,87
0	7.60	9.51	12,38	9,83
48-plot averages	9.47	13.30	15.97	12.92*
	Calculated Acre-yield of Roots			
	tons	tons	tons	tons
50	21.62	21.96	22.03	21,87
25	21.25	21.16	21,15	21,19
0	20.18	20,32	20,82	20,44
48-plot averages	21.02	21.15	21,33	21.17*
	Sucrose Percentage as Determined from Samples			
	percent	percent	percent	percent
50	16.86	16,89	16,78	16,84
25	16.40	16,61	16,39	16,47
0	16,47	16.45	16.45	16,46
48-plot averages	16.58	16.65	16,54	16,59*
	Calculated Acre-Yield of Gross Sugar			
	tons	tons	tons	tons
50	3.604	3.704	3,691	3,666
25	3,487	3,512	3,466	3,488
0	3,323	3,348	3,429	3,367
48-plot averages	3,471	3,521	3,529	3,507*
	Gross Sugar for 10 inches of water			
	tons	tons	tons	tons
50	3.02	2.21	1.89	2.37
25	3.93	2.58	2.16	2.89
0	4.37	3.53	2.77	3.56
48-plot averages	3.77	2.77	2.27	2.94*
Differences required for significance	gross sugar	tons roots	percent sucrose	
4-plot averages	0,215	1,00	.38	
12-plot averages, inches of water per irrigation	0.117	.55	.25	
12-plot averages, level of soil moisture	0.120	.54	.27	

*Mean for all plots (144 plots).

These 6 groups of treatments seem to fall into 3 general classes; namely, (1) plots receiving the 6-inch irrigations and the plots receiving applications of irrigation water when 50 percent of the available soil moisture still remained in the soil are very similar in that they have very slight variations in amount of water used and in crop yields. (2) The next similar group is comprised of the plots receiving the 4½ acre-inch applications, and the plots in which water was applied when 75 percent of the available soil moisture was used. (3) The last group consists of the plots to which 3 acre-inches of water were applied at each irrigation and those to which irrigation was not applied until the available soil moisture had been approximately exhausted in the first foot of soil. Within these classifications, we find small variation in use of water, yield of beet roots per acre, sucrose content of beets, gross sugar per acre, or amount of gross sugar produced per acre-inch of water applied. The interesting feature regarding these three classifications is that the 2 treatments using the greatest amount of water used approximately 19 percent more water than the intermediate class and approximately 40 percent more water than the least irrigated class. The variation of 40 percent of use in water is contrasted with a maximum variation of only 6.5 percent acre-yield of sugar-beet roots. The sucrose percentages of the roots show only very slight variation and the gross sugar per acre maximum variation is only 8.2 percent below the maximum yield. This would indicate that in comparing the plots that used the greatest amounts of water with those that used the least, 60 percent of the total water used produced slightly over 90 percent of the crop and the additional 40 percent of the water produced less than 10 percent of the crop.

Consideration of certain of the 9 different treatments may afford a better method of determination of the proper system for irrigation than the preceding discussion of the means of treatments. The greatest amount of water was applied to those plots that received 6 acre-inches of water per irrigation at times when the available soil moisture was reduced only to the 50-percent level. The least amount of water was applied to the plots in which 3 acre-inches of water were applied per irrigation at a time when approximately 100 percent of the available soil moisture had been used. Only 39 percent as much water was used in the second as in the first method of watering. All other treatments are in between these two mentioned in amount of water used, tons of beets produced per acre, and pounds of gross sugar per acre. The variation in use of water by these 2 treatments is large since 2½ times as much water was used by one treatment as by the other. In contrast of this wide divergence in water application there is only approximately 10 percent variation in tons of roots harvested and gross sugar per acre produced from plots receiving these two types of irrigation, the advantage being in favor of the plots receiving the most water. This indicates that on this type of land 90 percent of the maximum sugar-beet crop was produced by the use of only

39 percent of the applied water. Stated another way, a given supply of water could be used at the heavy watering rate to produce 39 acres of beets yielding 22.0 tons per acre, or a total of 858 tons, whereas the same total amount of water with a better distribution could have been used to grow 100 acres of beets and to produce 2,020 tons of sugar-beet roots.

There is one other type of treatment that deserves special emphasis. This treatment is perhaps the most logical one to be used in successful sugar-beet growing. It is the treatment that was given to those plots receiving 3 acre-inches of water per application with such a frequency as to maintain the available soil moisture level at 50 percent. This type of treatment received slightly less than 12 acre-inches of water per year as an average which is only 60 percent of the amount of water applied to the plots receiving the greatest amount of water. Here a decrease of approximately 40 percent of the amount of water used caused a decrease of only 2 percent from the maximum yield of sugar-beet roots.

A comparison of the application of 4½ and 6 acre-inches per irrigation and maintaining a soil moisture level of 50 percent or above shows that on these plots there was no difference in the yield of beets. This indicates that by the use of 4½ instead of 6 acre-inches of water per application, 14 percent of the water could have been saved without the reduction in the acre-yield of roots.

Conclusions

The treatment which is perhaps the most logical one to use in successful sugar-beet growing is the one in which 3 acre-inches of water were applied with a frequency which maintained the available soil moisture level at 50 percent. This type of treatment used 40 percent less water and produced within 2 percent of the tons of beets per acre that were produced on those plots having the maximum yield of beets and receiving the maximum amount of applied water.

The use of 3 acre-inches of water per application irrespective of degree of exhaustion of soil moisture indicates that a saving of 40 percent of the applied water may be made with a resulting loss of less than 2 percent of the yield of beets when comparison is made with an application rate of 6 acre-inches.

Forty percent less water was used in those treatments in which the available soil moisture was reduced to the approximate wilting point before irrigations were made if the comparison is made with plots irrigated so as to maintain the available soil moisture level at approximately 50 percent. This practice, however, was accompanied by a decrease of approximately 7 percent in the acre yield.

The above statements indicate methods whereby a 40 percent reduction could be made in the amount of applied irrigation water with only slight reduction in yields of sugar beets. Correspondingly, a 40 percent greater weight of sugar could be grown along with this economy in water use. The amount of time necessary to irrigate a given number of acres of beets would also be reduced. A 40 percent reduction in the amount of applied irrigation water would greatly reduce the cost per acre where pumping methods are used to supply water. Similarly, this reduction in water use and improvement in distribution, would also be a very beneficial factor in avoiding the peak-load demands on irrigation canals.