Influence of Crop-Sequence and Fertilizers Upon the Sugar Beet Crop

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Beginning in 1935 and continuing until the end of 1943, the Division of Sugar Plant Investigations of the U. S. Department of Agriculture cooperated with the Ohio State Agricultural Experiment Station in an experiment designed to determine the influence of certain crops grown in one season upon the same crops when grown on the same soil during the following season. The experimental plan was changed in 1939 to include applications of commercial fertilizer each year to one-half of each crop plot.

The crops included in this experimental work were sugar beets, corn, oats, soybeans for hay, and soybeans for seed. One primary objective was to determine the influence of the sugar beet crop upon the crops grown following it; another was to determine the influence of the other crops upon the yield and quality of the sugar beet roots when the sugar beet crop was grown following the other crops; and a third objective was to determine whether the effects of the crop-sequence upon the yield and quality of the sugar beet roots were modified by the application of commercial fertilizer.

Previous reports (*1, 2*)[2] have described the plan of the experiment, the area where the work was located, the manner in which the work was carried on, and the yields obtained from the various crops included, as influenced by the crop-sequence and fertilization factors. Although the yields obtained from the various crops have already been reported in the articles referred to, additional data that have not been reported were taken on the sugar beet roots produced under the various crop-sequence and crop-sequence-fertilization conditions, and it is the purpose of this report to present all such information pertaining to the sugar beet crop.

The only way the effect the sugar beet crop had upon the yields of the following crop could be determined was by comparing the yields obtained from the crops when grown following sugar beets with the yields obtained from the same crops when grown under like conditions but following other crops. A summary of these results is given in table 1 where it will be noted that the crop-sequence influence of the sugar beet crop varied according to the crop grown following it. When sugar beets were grown following sugar beets, the yield obtained was

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[2]Italic numbers in parentheses refer to literature cited.

Table 1.—The crop-sequence influence of sugar beets.

When the experimental crop was grown following:	The average acre-yield of the indicated crop when grown following sugar beets and the average acre-yield of the same crop when grown following all the crops except itself and sugar beets.				
	Sugar beets	Corn	Oats	Soybean hay	Soybean seed
	tons	bushels	bushels	tons	bushels
AVERAGE YIELDS FOR SEVEN CONSECUTIVE SEASONS WHERE NO FERTILIZER HAD BEEN APPLIED TO THE SOIL					
Sugar beets	5.287	42.31	51.20	2.240	23.91
The other crops*	6.505	40.04	47.35	2.353	24.29
Difference	−1.218	2.27	3.85	−0.113	−0.38
AVERAGE YIELDS FOR THREE CONSECUTIVE SEASONS WHERE FERTILIZER HAD BEEN APPLIED TO THE SOIL					
Sugar beets	8.891	50.26	65.98	2.360	21.10
The other crops*	10.663	47.32	56.00	2.422	22.51
Difference	−1.772	2.94	6.98	−0.062	−1.41
DIFFERENCES STATED IN PERCENTAGES OF THE MEAN YIELDS OBTAINED FOLLOWING SUGAR BEETS					
Seven seasons results	−23.05	5.37	7.52	−1.92	−1.59
Three seasons results	−19.93	5.85	10.58	−2.63	−6.68

*The average yield of beets following the other four crops and the average yields obtained from the other crops following all the crops except sugar beets and itself, i. e., three crops.

seriously depressed; when the soybean crops were grown following sugar beets, the yields were slightly but not seriously depressed; but when corn or oats were grown following the sugar beets, both the 7-year and the 3-year average yields obtained were somewhat better than the average yields obtained when either of these crops were grown following the other crops included in this experiment. So it would seem, as far as the results of this experimental work are concerned, that the sugar beet crop may be considered a good preparatory crop for either corn or oats; a fair preparatory crop for soybean seed or soybean hay; and a very poor preparatory crop for sugar beets.

The influence of the various crops upon the following sugar beet crop was determined through keeping a record of the numbers of marketable roots as well as of the yields obtained under the various crop-sequence conditions and also through taking samples of the roots produced upon each plot or sub-plot from which the sucrose percentages of the beet roots and the apparent purity coefficients of the beet juices were determined. This information is summarized in table 2 from which it will be noted that the numbers of roots, the acre-yields, the sucrose percentages, and the apparent purity coefficients, and also the calculated amounts of indicated available sugar produced per acre, all differed one from the other under the various crop-sequence conditions

and that with the exception of the apparent purity coefficients, statistically significant differences were found.

In view of the fact that with the exception of the crop-sequence conditions, all conditions were kept as nearly uniform as possible for the sugar beet crop during the course of this experimental work, such differences in numbers, in acre-yields, and in quality of the beet roots obtained are attributable to the differences in the crop-sequence conditions under which the sugar beet crop was grown.

The differences in numbers of marketable roots obtained under the various crop-sequence conditions are believed to be due largely to a soil sanitation effect of the preceding crops and the difference to be brought about by the fact that some of the crops discourage the growth of pathogenic soil organisms which attack the sugar beet seedlings and plants, whereas other crops either do not discourage the growth of such organisms or may actually favor it, thus creating conditions unfavorable to obtaining adequate stands of sugar beets. According to the results presented in table 2, the soybean and corn crops created a more favorable soil condition for the sugar beet seedlings and plants

Table 2.—The sugar beet crop as influenced by the crop-sequence factor.

When the sugar-beet crop was grown following	Characteristics of the sugar-beet crop when grown following the crop indicated.				
	Marketable roots per acre	Acre-yield	Sucrose	Apparent purity coefficient	Calculated production of indicated available sugar per acre
	number	tons	percentage		pounds
AVERAGE RESULTS FOR SEVEN CONSECUTIVE SEASONS OBTAINED WHERE NO FERTILIZER HAS BEEN APPLIED TO THE SOIL					
Sugar beets	11712	5.287	15.22	84.11	1352
Corn	14753	6.620	15.91	85.53	1624
Oats	13842	5.891	15.60	85.55	1530
Soybean hay	14318	7.275	15.84	85.31	1988
Soybean seed	15568	6.833	15.78	85.08	1825
With difference[1]	990**	0.610**	0.37*	1.21	177**
AVERAGE RESULTS FOR THREE CONSECUTIVE SEASONS OBTAINED WHERE FERTILIZER HAS BEEN APPLIED TO THE SOIL					
Sugar beets	13158	8.763	15.21	84.41	2062
Corn	16812	9.396	16.26	85.73	2558
Oats	16235	9.190	15.96	85.59	2459
Soybean hay	17238	11.589	16.06	85.57	3160
Soybean seed	17594	10.476	15.96	85.19	2804
With difference[1]	1757*	1.221**	0.51**	1.17	379**

[1] Difference necessary for significance at the 5-percent level.
* Differences statistically significant to the 5-percent point.
** Differences statistically significant to the 1-percent point.

than did the oat crop, and the oat crop created a much more favorable condition for the beet plants than did sugar beet plants themselves.

Although the acre yields of sugar beet roots obtained under the various crop-sequence conditions were different, as shown in table 2, when the rankings of the yields and the numbers of marketable roots are compared it becomes evident that the yields, being so nearly in the same order as the numbers of marketable roots, were determined very largely by the numbers of marketable roots obtained. If the yields obtained were determined entirely by the numbers of marketable roots, it might be expected that the average weights of the roots produced under the various crop-sequence conditions would be nearly the same, or since it is well known that with all other conditions being equal there is a negative relationship between the number of roots produced upon a given area and the average weight of those roots, that the ranking of the average weights of the roots produced would be the exact reverse of the ranking of the numbers and that there would be a straight-line relationship between the numbers of marketable roots and the average weight of the roots. So far as the average weights of the roots produced in this experimental work are concerned, neither assumption is entirely correct. When the average weights of the roots are plotted against the numbers as is shown in figure 1, it will be seen that there is a negative and approximately straight-line relationship between the numbers of roots and the average weights of the roots produced by those beets grown following the sugar beet, corn, and oat crops as shown by the solid lines in figure 1, but that the average weight of the roots produced following the soybean crops, as shown by the broken lines, do not abide by the same rule. It must be concluded therefore that the growth of the soybean hay and soybean seed crops upon the soil during one season benefited the sugar beet crop of the following season not only in the numbers of marketable roots obtained but also in the average weights of the individual roots.

A summary of the sucrose percentages of the beet roots and the apparent purity coefficients of the beet juices, as determined by the analysis of the samples taken from each of the plots or sub-plots under each of the crop-sequence conditions, revealed that differences did exist in the quality of the beet roots harvested. However, so far as statistical significance or appreciable difference is concerned, this difference in quality was entirely between those sugar beet roots produced following sugar beets and those beet roots produced following any of the other erops. The sugar beet roots produced on the soil which had produced sugar beets during the preceding year were definitely lower in quality than the beet roots produced following any of the other crops.

Beginning with the season of 1939, a fertilization factor was in-

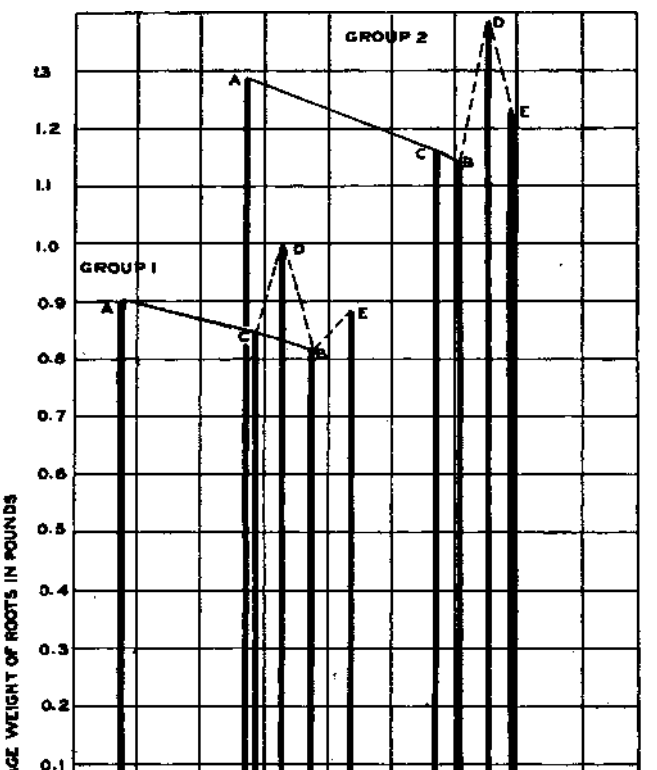


Figure 1.—Number and average weight of roots produced under the various crop-sequence conditions. Group 1. Results obtained during seven consecutive seasons where no fertilizer had been appiied. Group 2. Results obtained during: three consecutive seasons where fertilizer had been applied.

The preceding crops were: A, sugar beets: B, corn; C, oats; D, soybean hay; E, soybean seed.

trodueed into the experimental plan. This was accomplished through the application of 300 pounds per acre of a 4-10-6 fertilizer mixture to one half of each of the crop strips each season. In even numbered years the west half of each crop strip received the application of fertilizer and in the odd numbered years, the north half of each crop strip was fertilized. This resulted in each crop-plot being divided into four sub-plots according to the fertilization conditions which can be designated as:

Fertilized both current and preceding years,
Fertilizer current but not preceding year,
Fertilized preceding but not current year,
Fertilized neither current nor preceding year.

The results were recorded according to both the crop-sequence condition and the fertilization condition under which they were obtained.

It was possible to determine from the results obtained under the various fertilization conditions if the crop-sequence effect had been modified in any way by the fertilization. The statistical analysis of the data obtained, as reported previously *(1)* did show that there was an interaction between the crop-sequence influence and the fertilization factor with significance to the 5 percent level when the acre yields were considered but that there was no interaction discernible so far as the numbers of marketable roots, sucrose percentages, or apparent purity coefficients were concerned. The fertilization conditions did, however, modify the numbers of marketable roots and the yields obtained and also the quality of the roots as shown in table 3 and figure 2. From this table it will be noted that higher numbers of marketable roots, better acre-yields, and better quality roots were obtained when the fertilizer had been applied to the sugar beet crop in the current year than when it had been applied to the preceding crop ; and the results were better when the fertilizer had been applied to the preceding crop than when none had been applied. The average size of the sugar beet roots obtained as shown in figure 2, became larger with the increase in the fertilization factor, in spite of the greater number of marketable roots being produced upon a given area.

The sugar beet crop has been grown in the eastern agricultural areas for more than 50 years. In those sections where yields have been satisfactory and where factories have been established, the sugar beet crop has been adopted and has been incorporated into the cropping systems being followed. However, even in these sections, opinions and beliefs are often encountered which credit the sugar beet crop with exerting a deleterious effect upon the soil and thus upon the yield to be obtained from the crop following. The results obtained in this experimental work which, for that part which did not include fertiliza-

Table 3.—Effect of the fertilizatlon conditions upon the yield and quality of the sugar beet roots.

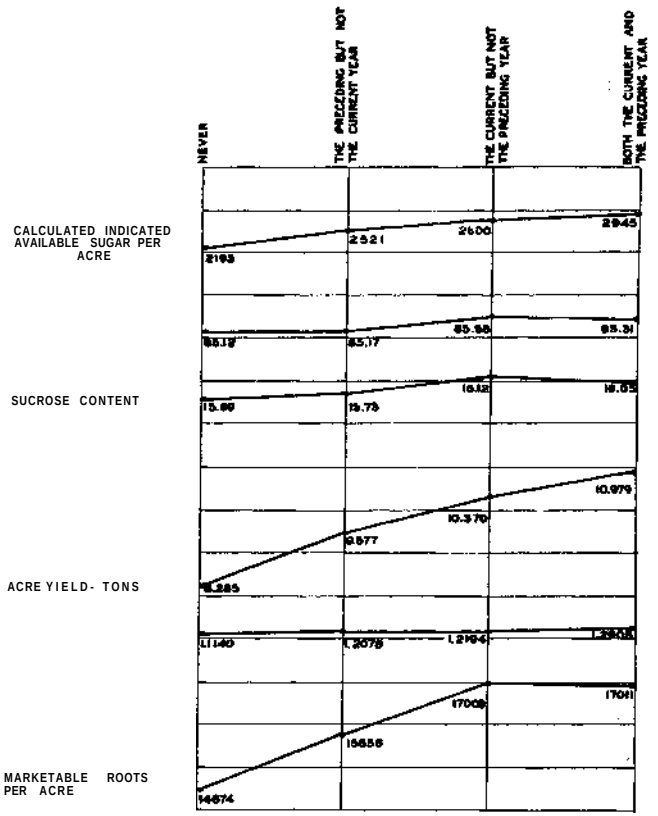
When grown where 300 pounds per acre of a 4-10-6 fertiliser mixture had been applied when indicated	Characteristics of the sugar beet crop when grown under the various fertilization conditions: Marketable roots per acre	Acre-yield	Sucrose	Apparent purity coefficient	Calculated production of indicated available sugar per acre
	number	tons	percentage		pounds
Current and preceding years	17011	10.979	16.05	85.31	2945
Current but not preceding year	17008	10.370	1(5.12	85.58	2800
Preceding but not current year	15858	9.577	15.73	.85.17	2521
Neither current nor preceding year	14874	8.285	15.69	85.12	2183
With difference[1]	528**	0.418**	0.31*	0.86	144**

[1] Differences necessary for significance at the 5-percent level.
* Differences statistically significant to the 5-percent point.
** Differences statistically significant to the 1-percent point.

tion, was carried on through seven consecutive seasons and through three consecutive seasons for that part which did include fertilization, indicate very definitely that the sugar beet crop does not exert a generally deleterious effect upon the soil as reflected by the yields obtained from the crops following. In fact it was only when sugar beets were grown following sugar beets that a definite deleterious effect was found. When other crops were grown following the sugar beet crop, no appreciable deleterious effect was found and in the case of two of the crops commonly included in many rotations throughout the eastern agricultural areas, the crop-sequence influence of the sugar beet crop was found to be beneficial.

The sugar beet crop was also found to respond quite favorably to the fertilization factor. Not only were the numbers of marketable roots and the yields increased by the application of fertilizer, but the quality of the roots was also bettered. These benefits, each of which may not be so very great in itself, are combined in the objective of the crop—the amount of recoverable sugar indicated per acre—and the total difference caused by the fertilization is found to be very appreciable.

The results to be obtained from the sugar beet crop are found to be definitely influenced by the crop-sequence effect of the crop preceding it. This crop-sequence effect was apparent in the numbers of marketable roots, average weight oE the roots obtained, the yield, and also the quality of the roots produced. The benefits to be derived from



y .— Figure 2.—Response of sugar boets to applications of fertilizer when 300 pounds g ^ Per acre < * a 4_10n6 *«*•»« ^d been applied as indicated. Three soasonfdata

favorable crop-sequence conditions with the sugar beet crop can be obtained without additional expense in the production of the crop and hence should be given careful consideralion.

The results obtained in this experimental work have shown that, the success of the sugar beet crop is influenced both by the crop-sequence conditions under which it is grown and also by the fertilization of the soil. The results indicate, however, that the two factors operate practically independently of each other in exerting their influence upon the sugar beet crop. In the statistical analysis of the data, it was determined thai only in the case of the yields was the crop-sequence effect modified to any extent by the fertilization factor and this modification was relatively slight, being only of the Ji-percent order of significance. With all the other characteristics of the crop, the two factors were found to be independent of each other. Thus it may be concluded that the handicap derived from a poor cropping system with the sugar beet crop cannot be offset by a good fertilization program nor can the benefits to be derived from .needed fertilization be nullified by a good crop-sequence condition.

From the material presented in this report it may be concluded that:

1. The sugar beet crop may be a good or a fair preparatory crop according to the nature of the following crop but it does not exert a generally deleterious effect except when sugar beets are grown following sugar beets.
2. The sugar beet crop itself varies in all its characteristics under the influence of the crop-sequence factor.
3. Basing conclusions upon the numbers of marketable roots obtained, soybeans grown for seed, and corn, create conditions within the soil that are favorable to obtaining stands of sugar beets significantly higher than were obtained with other crops. Consideration of the acre-yields obtained indicates that soybeans as grown either for seed or hay brought about conditions favorable for production of sugar beet yields significantly higher than those obtained when sugar beets followed the other three crops in these tests.
4. The quality of the sugar beet roots, as well as the number of marketable roots and acre-yield, is depressed by growing sugar beets following sugar beets.
5. The sugar beet crop responded to the application of fertilizer by an increase in. the numbers of marketable roots, by an increase in the average weight of those roots, and by a slight betterment of the quality of such roots.
6. The statistical analysis of the data indicated no modification of the crop-sequence factor effect on the sugar beet crop by the fer-

tilization factor except with the yields where some slight modification was determined. 80 far as the numbers of marketable roots, sucrose percentages, and apparent purity coefficients were concerned, the two factors apparently operated entirely independently of each other.

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Yield, Percentage of Sucrose, and Coefficients of Apparent Purity of Sugar Beets as Affected by Rotational, Manurial, and Fertilizer Practices at the Dominion Experimental Station, Lethbridge, Alberta

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The Dominion Experimental Station is located near the city of Lethbridge, Alberta, which is 200 miles northwest of Great Falls, Mont. The Station is approximately in the center of the sugar beet growing area of Southern Alberta which annually produces about 30,000 acres of sugar beets. Nine year production averages (1936-1944) for the area are: Tons of beets per acre, 12.18; percentage of - sucrose, 17.85; sugar extracted per ton of beets, 302.76 pounds.

The purpose of this paper is to present information from some of the sugar beet cultural experiments which have been conducted almost continuously through the 4 decades of the Station's existence. The results discussed herein were secured from a long-term rotational experiment which was originally laid down on an old alfalfa field known to have some phosphorous deficiency. This deficiency now has been accentuated to the extent that sugar beet production on some of the check plots is decidedly uneconomic.

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