A Study with Sugar Beets on Two Fertility Levels of Soil

Rocky Ford, Colorado — Years 1938-40, Inclusive

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Results of study conducted in 1938 with two varieties of sugar beets, both moderately resistant to **leafspot,** one a sugar and the other a tonnage type, have been reported elsewhere (1)[2]. The combined results of the 1938 and 1939 studies were presented before this Society in 1940 (2). The present paper concludes this study, and deals with results obtained during the 3 years 1938-40 inclusive, on varietal response to varying levels in soil fertility combined with varying spacing effects between beets in the row.

Results of Previous Studies

In the 1938 study, the results indicated that the sugar variety Avas a weak feeder, in that it did not efficiently utilize additional amounts of commercial-fertilizer application beyond 40 pounds plant food per acre. On the other hand, the tonnage variety proved to be a strong feeder, responding in increased yields of tons beets per acre, percentage sucrose, and pounds sugar per acre, to increases in fertilizer application.

In 1939, the study Avas repeated, using the same varieties and the same amounts of the various fertilizer combinations used in 1938. In the 1939 test, and contrary to the results of the previous year's test, the sugar variety efficiently utilized fertilizer amounts greater than the 40-pound plant-food application. To secure additional information on this point, the study was repeated in 1940.

Materials and Methods

The soil type on which the 1940 study was conducted is classified as Rocky Ford fine sandy loam with a pH of 7.4. In cropping sequence, the same practice Avas followed as for the 1938 and 1939 studies previously reported. Cattle manure at the rate of 8 tons per acre was applied prior to plowing in the fall. The seedbed was prepared in late March and planting made during the second week in April at the rate of 20 pounds of seed per acre. The two domestic varieties of sugar beets used were of the same uniformity as to type as those used in the 1938 and 1939 tests,

The commercial fertilizers used Avere the same as those used in previous tests, namely: 4-16-4, 4-16-0, and 0-16-4 mixtures, in comparison with unfertilized check plots. The same amount of plant food per acre was applied from each mixture assuring thereby **a** comparison of equal amounts of plant food regardless of the difference

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[2]Figures in parentheses refer to Literature Cited.

in formula used. The rates of application were 200 and 400 pounds per acre, of the equivalent of a 20 percent mixture; thus 40 and 80 pounds, respectively, per acre of total plant food were applied. All the fertilizer was applied with the seed at time of planting.

The plot arrangement was fully randomized and of such layout as to permit unbiased evaluation of interactions between varieties, treatments, and rates of fertilizer application. Bach treatment was replicated sevenfold, the plots being 4 rows wide and 100 feet long. The distance between rows was 20 inches. One hundred twenty-six plots were included in this study. The beets were thinned to a distance of 12 inches in the row and grown to maturity under irrigation. The beets were harvested on an actual-yield basis, and analyzed for sucrose by the usual cold-water digestion method. The results in all eases represent an average of the seven replications. The data were analyzed by the variance method.

Experimental Results—1940

Table 1.—Results from fertilizer treatment with a sugar variety and a tonnage variety compared with no-treatment check plots.

	Sugar Variety			Tonnage Variety		
Formula	Rate of plant-food application			Rate of plant-food application		
Tons beets per acre	40 lb.	80 lb.	Check	40 lb.	80 lb.	Check
4-16-4	16.70	15.20	16.13	18.28	18.81	17.96
4-16-0	16.12	15.70	16.12	19.30	19.06	18.68
0-16-4	15.59	14.93	14.83	18.58	19.63	18.02
Average	16.14	15.31	15.69	18.72	19.21	18.22
Req. for Sig.	1.08 tons for single treatments .97 ton for averages of three treatments					
Percentage sucrose						
4-16-4	18.00	17.74	18.14	15.88	16.20	15.87
4-16-0	17.87	17.87	17.98	15.72	16.09	16.14
0-16-4	17.92	17.84	18.11	15.86	15.69	15.49
Average	17.93	17.82	18.08	15.82	15.99	15.83
Req. for sig.	.33 percent for single treatments .1907 percent for averages of three treatments					
Pounds sugar per acre yield						
4-16-4	6008	5414	5844	5706	6214	5707
4-16-0	5756	5503	5801	6076	6140	6008
0-16-4	5589	5241	5381	5851	6167	5560
Average	5784	5439	5675	5918	6140	5758
Req. for sig.	666.7 pounds for single treatments 385.3 pounds for averages of three treatments					

From a study of the results of this test, it is observed that the trend in fertilizer response is in favor of the 40-pound plant-food application for the sugar variety and the 80-pound application for the tonnage variety.

Combined Results of Fertilizer Tests

In table 2, the combined average results of the 3 years are given. These results were obtained from tests involving the two varieties and the three kinds of fertilizers used in varying amounts compared with no-treatment check plots.

Table 2.—Average results from fertilizer treatment with two varieties of sugar beets. Years 1938-1940, inclusive.

Fertilizer	Sugar Variety: Tons beets per acre	Sugar Variety: Percentage sucrose	Sugar Variety: Lb. sugar per acre	Tonnage Variety: Tons beets per acre	Tonnage Variety: Percentage sucrose	Tonnage Variety: Lb. sugar per acre
40 lb. Plant Food per Acre						
4-16-4	15.72	17.26	5161	17.55	15.50	5460
4-16-0	14.87	17.11	5151	17.79	15.42	5509
0-16-4	14.75	17.11	5074	17.14	15.58	5355
Average	15.15	17.16	5229	17.49	15.50	5441
Check	14.04	17.14	4849	16.93	15.50	5261
In favor of fertilizer	1.11	.02	380	.56	.00	180
80 lb. Plant Food per Acre						
4-16-4	14.65	17.11	5043	17.96	15.82	5690
4-16-0	14.71	16.91	5024	18.07	15.68	5961
0-16-4	14.91	17.45	5168	18.24	15.47	5666
Average	14.77	17.16	5078	18.39	15.66	5772
Check	13.92	17.08	4797	17.20	15.45	5323
In favor of fertilizer	.85	.08	281	1.19	.21	449
Req. for Sig.*	.72(a) .42(b)	.20(a) .12(b)	147(a) 85(b)			

*Exceeds 5 percent point (a) between individual fertilizer treatments.
(b) between average of fertilizer treatments.

Discussion of Results

Tons Beets per Acre.—From these average data, some interesting information is revealed. Over the 3-year period, the sugar variety utilizes more efficiently the lesser amounts of plant food. The increase over the unfertilized cheek was 1.11 tons per acre compared with .56 ton for the same comparison with the tonnage variety. The difference of .55 ton beets per acre in favor of the sugar variety is significantly large, demonstrating that this result was due to varietal effect. Of the fertilizer mixtures, the 4-16-4 treatment was productive of highest yield in tons beets per acre of the sugar variety. No wide differences in yield were obtained for the tonnage variety for the different fertilizer mixtures.

The reverse condition held for the heavier rate of plant-food application. The tonnage variety generally utilized the increased amount of plant food to better advantage. The increase over the

unfertilized check was 1.19 tons compared with .85 ton for the sugar variety. This difference, while not significant, is suggestively large, and is indicative of the greater feeding ability of the tonnage variety when a higher fertility level obtains. The 4-16-0 fertilizer mixture was the highest-yielding treatment in the 80-pound plant-food application with the tonnage variety. No appreciable differences were shown for the sugar variety.

Percentage Sucrose.—Except for the response from the 80-pound application rate of plant food to the tonnage variety, the differences for percentage sucrose in the beets were too small to reach significance, when the average of all treatments and the unfertilized checks are compared. However, for the sugar variety, in the 80-pound plant-food application rate, the 0-16-4 treatment was better than either the 4-16-4 or 4-16-0 mixtures. The 4-16-0 treatment depressed the sucrose content to a significant degree.

In the tonnage variety, the highest sucrose value was obtained from the 4-16-4 fertilizer mixture and the lowest from the 0-16-4 mixture in the 80-pound plant-food application rate. The 4-16-0 fertilizer was intermediate in response indicating that the tonnage variety reacted favorably to a nitrogen-bearing fertilizer.

It is also apparent, that regardless of fertilizer treatment, the sugar and tonnage varieties performed essentially according to variety designation.

Pounds Sugar per Acre.—For the sugar variety, the yield of sugar per acre followed the beet-tonnage trend. The highest-yielding treatment in the 40-pound application rate was the 4-16-4 mixture, which easily outyielded the companion 4-16-0 and 0-16-4 treatments. X<> significant differences were shown for any of the treatments in the tonnage variety for the lesser application rate. Comparing the difference between the differences shown for the sugar variety over the unfertilized check with that of the tonnage variety, it is evident that the sugar variety was a much more efficient producer of sugar per acre from lesser applications of plant food.

Jn the heavier application rate, these trends were reversed. The 4-16-0 treatment was the highest-yielding mixture for the tonnage variety, exceeding both the 4-16-4 and 0-16-4 fertilizer in this respect. For the sugar variety no reliable differences were shown. However for both varieties, large differences were obtained in favor of the fertilizer treatments compared with the no-fertilizer treatments.

Comparing the increase of 449 pounds sugar per acre arising from the fertilizer application to the tonnage variety with that of the sugar variety, a difference of 168 pounds more sugar per acre in favor of the tonnage variety is shown, which difference is highly significant.

From the foregoing results, it appears that under the conditions of these tests, the sugar variety utilized to a higher degree lesser ap-

plications of plant food, and the tonnage variety was more efficient when larger applications of plant food were made. In view of the greater differences in pounds sugar per acre yield obtained in favor of fertilizer application compared with no fertilizer, and that differences in kind.-; of fertilizer are of secondary importance, it is obvious that the most necessary plant-food element in these tests was phosphoric acid. This conclusion confirms generally the standard commercial fertilizer practice prevailing in this area.

Spacing Tests with Sugar Beets

In the study initialed in 1938 on varietal response to different levels of soil fertility, indications were that distance of spacing beets in the row would also have to be considered. Therefore, in 1939, a 10-inch and a 15-inch spacing variable was added to the study. From the 10-inch spacing between plants in the row, the largest increases in pounds sugar per acre were obtained, regardless of variety or soil treatment. The conclusions reached were that the commonly recommended 10 to 12-inch spacing between plants in the row in most irrigated areas is not far from what is required for best results from most of our present varieties of sugar beets.

In 1940, the study of spacing intervals in the row with sugar beets grown on a high and average-fertility level of soil was repeated. The same field selected for the high and average-fertility level work was used for these spacing studies. As in 1939, 500 pounds of 4-16-4 fertilizer mixture were applied to the fertilized plots with the seed. The same sugar and tonnage varieties were used as in the previous tests. Plots were 4 rows wide, 100 feet long, with 7 replicates for each variable tested, or a total of 56 plots. Spacing interval at time of thinning was 10 and 15 inches between beet plants in the row. Harvest was made on an actual-yield basis.

Table 3.—Results of sluicing tests with two varieties of sugar beets, grown on two fertility levels of soil—1940.

	Sugar Variety		Tonnage Variety	
	Fertilized	Not fertilized	Fertilized	Not fertilized
Tons beets per acre				
10-in. Spacing	15.97	14.16	17.61	15.66
15 in. Spacing	14.45	14.24	17.52	15.45
Req. for Sig.	1.72*			
Percentage sucrose				
10-in. Spacing	17.84	17.26	15.35	15.33
15 in. Spacing	17.05	17.23	14.54	14.90
Req. for Sig.	.47**			
Pounds sugar per acre				
10-in. Spacing	5446	4885	5416	4798
15-in Spacing	4082	4910	5107	4607
Req. for Sig.	378**			

*Significance beyond 5 percent point. **Signifieance beyond 1 percent point.

It is evident from the results obtained that increased yields of pounds sugar per acre were in favor of the closer-spacing interval for both varieties of sugar beets receiving fertilizer treatment. In the unfertilized plots, the decrease in yield was more marked for the tonnage variety than for the sugar variety, both spacings combined.

Combining the data for 1939 and 1940, the trends shown in table 4 are obtained.

Table 4.—Effects of two spacing intervals and two fertility levels of soil upon two varieties of sugar beets.—Years 1939-1940.

	Sugar Variety			Tonnage Variety		
	Fertilized	Not fertilized	Average	Fertilized	Not fertilized	Average
Tons beets per acre						
10-in. Spacing	17.38	16.15	16.77	21.47	19.61	20.56
15-in. Spacing	15.79	14.34	15.07	18.69	16.85	17.67
Average	16.50	15.25		19.98	18.23	
In favor of 10-in. Spacing			1.70			2.89
Req. for Sig.						
Single treatments		1.32**				
Average of two treatments		.94				
Percentage sucrose						
10-in. Spacing	17.04	17.21	17.13	14.88	15.00	14.94
15-in. Spacing	16.96	16.93	16.94	14.21	15.00	14.62
Average	17.00	17.07		14.55	15.00	
In favor of 10-in. Spacing			.19			.45
Req. for Sig.						
Single treatments		.39				
Average of two treatments		.27				
Pounds sugar per acre						
10-in. Spacing	5932	5662	5797	6442	5859	6151
15-in. Spacing	5407	4856	5132	5260	4989	5125
Average	5670	5260		5851	5424	
In favor of 10 in. Spacing			665			1026
Req. for Sig.						
Single treatments		365				
Average of two treatments		259				

**Significance exceeds 1 percent point.

Both varieties responded to closer spacings of beets in the row. the increases were more marked for the tonnage variety than for the sugar variety, indicating greater ability of the tonnage variety to compete for plant food. As an average of both varieties, fertilizer, and non-fertilizer treatments combined, the tonnage variety produced

1.19 tons more beets, ,26 percent higher sucrose in the beet, and 361 pounds greater yield of sugar per acre from the 10-inch spacing interval, than was obtained from spacing beets 15 inches apart in the row. This however is only a part of the actual result, since both the sugar and the tonnage varieties performed essentially according to type designation, which is shown in the following comparison ; when spacings are disregarded, and varietal response to fertilizer treatment alone is considered, the tonnage variety outyielded the sugar variety 3.39 tons beets per acre, a highly significant difference. However, when the difference in percentage sucrose is considered, this was 2.45 percent higher for the sugar variety, which also is a highly significant difference. The balancing effect of the greater tonnage yield of the one compared to the greater percentage sucrose in the other, resulted in a non-significant increase of 181 pounds sugar per acre in favor of the tonnage variety.

When each variety is considered separately, it is seen that the sugar variety produced significantly large increases in tons of beets and pounds sugar per acre for the 10-inch spacing compared with the 15-inch spacing interval for both the fertilized and non-fertilized treatments. The sugar variety also maintained its percentage sucrose values in a fairly stable manner under the conditions of increased fertilization and increased spacing interval of beets in the row. In these same comparisons, the tonnage variety performed in somewhat similar manner but to a more pronounced degree in tons beets and sugar per acre yield. However, under the influence of wider spacing, the sucrose value was sharply depressed with the addition of fertilizer, indicating that in this variety the character for percentage sucrose was not stable when a wider range of available plant food was encountered.

Summary and Conclusions

Under the conditions existing in the Arkansas Valley area in Colorado, years 1938 to 1940 inclusive, and with tests conducted on two levels of soil fertility with a sugar and a tonnage variety of sugar beets, both moderately resistant to leafspot, it was found that there was differential response of variety to more effective utilization of plant food. The sugar variety utilized more efficiently smaller applications of plant food, and the tonnage variety responded to more generous fertilization.

In comparing the effect of different kinds of fertilizers, with different rates of application, upon these two varieties, it was found that the sugar variety produced best yields with the 4-16-4 fertilizer, when applied at the rate of 40 pounds plant food per acre, and the tonnage variety responded most favorably to the 4-16-0 fertilizer at the 80-pound rate of application.

Comparing both varieties in a test where 10-inch and 15-ineh spacing intervals between beets within the row were employed on a high and average level of soil fertility, it was found that both the sugar and the tonnage varieties responded to closer spacings of beets in the row.

The percentage sucrose in the sugar variety remained fairly constant when the variety was subjected to increased fertilization and to an increased interval of spacing between beets in the row. On the other hand, the percentage sucrose in the tonnage variety was depressed sharply when the variety was subjected to these same conditions.

Both varieties produced under fertilization significantly higher sugar-per-acre yields for both spacing intervals, compared to the non-fertilized check plots.

Literature Cited

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Fertilizers—Manner of Application

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For many years there has been some question in the minds of men engaged in agriculture regarding the proper application of commercial fertilizers. Considerable experimental work has been carried on in various areas. To further these investigations with the idea of determining more fully the correct manner of application, an experimental plot was planned and conducted in the West Jordan district, Salt Lake County, Utah, during the 1940 season.

In order to care for variation in soil conditions, the randomized-block scheme was employed. Six methods of application were used and each was replicated four times. The two center rows in each block were used for selective harvest. The beets from each were cleaned and weighed in the field. The weights were checked by two persons in order to assure an accurate record.

The experiment was continued in 1941 in West Jordan, Utah, and Shelley, Idaho, districts on strip plantings comprising three replications. It was noted that moisture control and correct cultural methods had much to do with obtaining maximum results through

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