The Effect of Different Levels of Fertility on the Chemical Composition of Sugar Beets

G. C. Russell and S. Dubetz[1]

Received for publication March 28, 1958

The composition of sugar beets was reported by Dunn and Rost (4)[2] to vary according to the conditions under which the beets were grown. Various fertility practices were shown by Hill (5) to produce large differences in the yield of sugar beets on long-term rotation experiments at Lethbridge, Alberta. This paper reports the results of a study that was undertaken to assess the effect of soil fertility on the composition of sugar beets grown in two rotations at the Experimental Farm, Lethbridge.

The two rotations involved in this experiment were set out in 1929 with duplicate plots selected at random (i.e., for the 8-year rotation 16 plots were required) (5) on an old alfalfa field which showed signs of phosphorus deficiency. One was an 8-year rotation consisting of wheat seeded down to alfalfa, 3 years of alfalfa, wheat, 2 years of sugar beets, and wheat. In this rotation four management practices resulting in four levels of fertility were followed:

1. 30 tons of barnyard manure applied to the wheat stubble and plowed under in the fall preceding the first year of sugar beets.
2. 100 pounds of fertilizer (0-43-0 until 1948 and 11-48-0 since 1948) at the time of seeding with each of the two sugar beet crops.
3. Manure and fertilizer applied and handled as in 1 and 2.
4. No additions.

The other was a 4-year rotation consisting of wheat seeded down to sweet clover, clover hay, and 2 years of sugar beets. In this rotation six management practices were followed:

1. 20 tons of barnyard manure applied to the sweet clover stubble and plowed under in the fall preceding the first year of sugar beets. (Two crops of sweet clover hay were removed.)
2. 100 pounds of fertilizer (0-43-0 until 1948 and 11-48-0 since 1948) applied at seeding time with each of the two sugar beet crops.
3. Manure and fertilizer applied and handled as in 1 and 2.
4. No additions.

---

[1] Head, Field Husbandry Section, and Agronomist, respectively, Experimental Farm, Canada Department of Agriculture, Lethbridge, Alberta.

[2] Numbers in parentheses refer to literature cited.

Table 1.—The Effect of Management Practices on the 1956 and Long Term (1929-1956) Average Yield, Sucrose Content, and Apparent Purity of Sugar Beets Grown in an Eight-Year Rotation at Lethbridge, Alberta.

Treatment[1]	Root Yield		Sucrose Content		Purity	
	1956	Av.	1956	Av.	1956	Av.
	Tons/Ac.	Tons/Ac.	%	%	%	%
			First-Year Beets			
Manure and fertilizer	14.59	20.53	16.0	15.6	87.4	85.0
Manure	11.92	19.39	16.2	15.8	88.0	85.4
Fertilizer	11.44	13.53	15.2	15.7	87.4	85.4
No additions	2.22	4.94	16.7	15.3	86.0	84.2
			Second-Year Beets			
Manure and fertilizer	15.85	19.84	15.4	16.2	88.1	85.8
Manure	15.59	18.35	14.2	16.3	86.6	85.7
Fertilizer	11.80	15.19	14.9	15.8	88.2	85.4
No additions	5.50	6.20	15.2	15.6	88.4	84.6

[1] 30 tons manure plowed under in the fall preceding sugar beets and 100 pounds 11-48-0 applied at time of seeding sugar beets for each of the two crop years.

Table 2.—The Effect of Management Practices on the 1956 and Long Term (1929-1956) Average Yield, Sucrose Content, and Apparent Purity of Sugar Beets Grown in a Four-Year Rotation at Lethbridge, Alberta.

Treatment[1]	Root Yield		Sucrose Content		Purity	
	1956	Av.	1956	Av.	1956	Av.
	Tons/Ac.	Tons/Ac.	%	%	%	%
			First-Year Beets			
Manure and fertilizer	16.34	20.98	16.6	16.7	88.3	86.0
Manure	13.51	19.87	16.5	16.7	87.4	86.3
Fertilizer	14.85	16.01	16.9	16.5	87.1	85.7
No additions	6.02	8.59	15.4	16.2	89.0	85.6
Green manure and fertilizer	14.00	16.34	16.6	16.5	88.8	86.3
Green manure	4.64	8.84	15.9	16.2	86.4	85.6
			Second-Year Beets			
Manure and fertilizer	17.38	19.58	16.3	17.1	88.1	86.4
Manure	14.78	17.67	15.4	16.8	87.0	86.6
Fertilizer	16.92	16.00	14.9	16.5	87.2	86.0
No additions	9.36	8.60	16.1	16.1	87.0	85.4
Green manure and fertilizer	15.56	16.37	16.2	16.7	87.1	86.2
Green manure	9.54	8.36	13.7	16.0	85.1	85.0

[1] 20 tons manure plowed under in the fall preceding sugar beets and 100 pounds 11-48-0 applied at time of seeding sugar beets for each of the two crop years.

5. Second crop of sweet clover plowed under as a green manure and fertilizer as applied in 2.
6. Second crop of sweet clover plowed under as green manure.

Samples from all the sugar beet plots were taken from both rotations in 1956 at the time of harvest. The roots were cut into small cubes and dried at 180° F. to determine the moisture content. The dried samples were then ground and kept in glass containers for analysis. The following methods were used for determining the various constituents: Ash by ignition and total nitrogen by Kjeldahl method (1), phosphorus by molybdate method (7), magnesium by versenate method (2), calcium, sodium, and potassium by means of the flame photometer (6).

Results

The 1956 and long-term average yields, sucrose percentages, and apparent purity for both sugar beet crops in the 8-year rotation are shown in Table 1. Comparable data for the 4-year rotation appear in Table 2. The yield of dry matter and the chemical content of sugar beet roots produced in 1956 are shown in Table 3 for the 8-year rotation and in Table 4 for the 4-year rotation.

Table 3.—The Effect of Management Practices on the Mineral Content of Sugar Beet Roots Grown in an Eight-Year Rotation at Lethbridge, Alberta, 1956.

Treatment[1]	Dry Matter	Ash	N	P	K	Na	Mg	Ca
	Lb./Ac.	%	%	%	%	%	%	%
			First-Year Beets					
Manure and fertilizer	6,157	2.71	0.92	0.094	1.128	0.205	0.287	0.092
Manure	5,030	3.32	1.04	0.068	1.410	0.310	0.304	0.116
Fertilizer	4,828	2.98	0.98	0.086	1.190	0.315	0.271	0.102
No additions	937	3.60	1.28	0.076	1.580	0.185	0.252	0.137
Average	4,238	3.15	1.06	0.081	1.327	0.254	0.278	0.112
			Second-Year Beets					
Manure and fertilizer	6,689	3.62	1.06	0.121	1.345	0.475	0.305	0.103
Manure	6,579	3.83	1.12	0.097	1.465	0.510	0.392	0.114
Fertilizer	4,980	3.66	1.12	0.086	1.470	0.315	0.308	0.134
No additions	2,321	3.44	1.06	0.064	1.628	0.255	0.306	0.132
Average	5,142	3.64	1.09	0.092	1.477	0.389	0.328	0.121

[1] 30 tons manure plowed under in the fall preceding sugar beets and 100 pounds 11-48-0 applied at time of seeding sugar beets for each of the two crop years.

Table 4.—The Effect of Management Practices on the Mineral Content of Sugar Beet Roots Grown in a Four-Year Rotation at Lethbridge, Alberta, 1956.

Treatment[1]	Dry Matter	Ash	N	P	K	Na	Mg	Ca
	Lb./Ac.	%	%	%	%	%	%	%
First-Year Beets								
Manure and fertilizer	6,895	2.22	0.70	0.161	1.020	0.065	0.139	0.102
Manure	5,701	2.73	0.64	0.169	1.265	0.130	0.142	0.087
Fertilizer	6,267	2.20	0.66	0.114	0.823	0.068	0.150	0.123
No additions	2,540	2.97	0.80	0.092	1.333	0.140	0.270	0.114
Green manure and fertilizer	5,908	2.58	0.78	0.126	1.130	0.105	0.225	0.107
Green manure	1,958	2.92	0.85	0.081	1.198	0.195	0.291	0.125
Average	4,878	2.60	0.74	0.124	1.128	0.117	0.203	0.110
Second-Year Beets								
Manure and fertilizer	7,334	2.92	0.75	0.172	1.265	0.280	0.191	0.090
Manure	6,237	3.69	1.00	0.142	1.505	0.513	0.230	0.075
Fertilizer	7,141	2.77	0.72	0.138	1.103	0.210	0.274	0.091
No additions	3,950	3.09	0.84	0.096	1.205	0.258	0.245	0.099
Green manure and fertilizer	6,566	3.05	0.88	0.124	1.115	0.310	0.243	0.109
Green manure	4,026	3.52	1.00	0.099	1.315	0.415	0.184	0.114
Average	5,876	3.17	0.86	0.128	1.251	0.331	0.228	0.096

[1] 20 tons manure plowed under in the fall preceding sugar beets and 100 pounds 11-48-0 applied at time of seeding sugar beets for each of the two crop years.

Discussion

The striking differences in yield as shown in Tables 1 and 2 definitely point out the value of manure and phosphatic fertilizer in sugar beet culture for southern Alberta. The sugar content and apparent purity of the beets were not influenced by fertility level to the same extent as was the yield.

As would be reasonable to expect, the dry matter content closely paralleled the yield trends. There was no definite trend in either the ash or nitrogen content of the beets, although the application of phosphorus to the first-year beets seemed to result in a lower nitrogen content of the beet roots. Apparently, the decomposition of the manure and green manure during the first year of sugar beet production resulted in more nitrogen being available for the second-year beets, so that the nitrogen content was higher in the roots of the second-year beet crop than in those of the first-year crop. The effect of phosphorus fertilizer on nitrogen content was not as apparent in the second-year beets.

Phosphorus seemed to be the most limiting element in these experiments, so the effect of phosphorus on the composition of the roots was very pronounced. An indication of the effect of the barnyard manure on phosphorus availability may be seen when the two rotations are compared. The 4-year rotation received 20 tons of manure every 4 years, and beets from this rotation contained more phosphorus than those from the 8-year rotation, which received 30 tons of manure every 8 years. The effect of the decomposing barnyard manure on phosphorus availability also is shown. In both rotations the sugar beets that received neither manure nor fertilizer had the lowest phosphorus content. Under the conditions of this experiment, the practice of plowing under green manure was of little value. This was probably due to the small amount of organic matter produced by the second crop of sweet clover.

Potassium has not been a limiting factor in the production of sugar beets in southern Alberta (3). The addition of phosphorus resulted in lower potassium content of the beets in every case but one, which could be a reflection of the differences in yield. The check plots, receiving no manure or fertilizer, produced low-yielding roots with a high potassium content.

No general patterns due to management practices were apparent in the sodium, magnesium, and calcium content of the sugar beet roots.

In no case were the differences in the amounts of the constituents of the sugar beet roots very great. There were greater differences in the amounts of these constituents as a result of rotation practices than there were because of management practices within the rotation. Management practices within rotations seemed to have a greater effect on yield than they had on the composition of the sugar beet roots at harvest. Differences in chemical composition may have important effects on the quality of the sugar beet roots, although sugar content and apparent purity within rotations in this experiment did not appear to be affected by the chemical composition.

Summary

The addition of phosphorus fertilizer, barnyard manure, and fertilizer and manure to phosphorus-deficient long-term rotation experiments resulted in large increases in the yield of sugar beet roots grown in the rotations.

The addition of phosphorus fertilizer resulted in higher phosphorus and lower potassium contents of the beet roots, and seemed to lower the nitrogen content of the first-year roots.

The addition of barnyard manure resulted in increased phosphorus availability in the soil as indicated by higher phosphorus content of beet roots grown on plots receiving manure.

Chemical analysis of the sugar beet roots showed only small variations in the composition of the roots.

Management practices within rotations seemed to have a greater effect on yield than they had on the composition of the sugar beet roots at harvest.

Literature Cited

(1) Assoc. Off. Agr. Chemists. 1950. Methods of analysis. 7th ed. Washington, D. C.

(2) CHENG, K. L., and BRAY, R. H. 1951. Determination of calcium and magnesium in soil and plant material. Soil Sci. 72:449-458.

(3) DUBETZ, S. 1954. The fertility balance in a ten-year sugar beet rotation after forty-two years of cropping. Proc. Amer. Soc. Sugar Beet Tech. 8:81-85.

(4) DUNN, L. E. and ROST C. O. 1949. Influence of fertilizers on composition and quality of sugar beets. Minn. Agr. Exp. Sta. Tech. Bul. 183.

(5) HILL, K. W. 1946. 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. Proc. Amer. Soc. Sugar Beet Tech. 4:63-72.

(6) RICHARDS, L. A. (Ed.) 1954. Diagnosis and improvement of saline and alkali soils. U.S.D.A. Agriculture Handbook 60.

(7) WARD, G. M., and JOHNSTON, F. B. 1953. Chemical method of plant analysis. Canada Dept. Agr. Science Service Contrib. 238.