Plant-Food Elements in Sugar Beets Throughout the Growing Season

H. D. BROWN AND H. Irving[1]

The object of nearly all agronomic study with sugar beets is to grow bigger beets of higher quality. Many factors that influence beet yields are uncontrollable, but there are sufficient over which we have some control to make progress possible and feasible. Among the controllable factors are those concerned with feeding the growing plant. Plant feeding is largely a matter of minerals in solution, and where these are available in sufficient quantities under normal sunshine and temperature conditions, the plants grow to enormous size, and yields per acre are far in excess of normal field yields.[2]

Plant-food elements for sugar beets are in the soil as a part of the soil's natural fertility or are added in some kind of fertilizer treatment. The controlling factors are "soil reserves" and "commercial fertilizers added."

Crop Analysis

One common method in estimating the beet crops' needs is to analyze the mature beet and calculate back the amounts of nitrogen, phosphorus, potash, calcium, etc.. which the plant took out of the soil, and recommend that these amounts be applied in a commercial fertilizer. Too many advocates of fertilizer treatments, to meet the needs of the sugar-beet crop, neglect to take into account the soil's available minerals. We have records of various analyses of sugar-beet roots and tops, and though the amounts vary considerably, as reported by different investigators, the general figures for the main plant-food elements approximate those published in the table and chart from the American Potash Institute in "Better Crops"—March. 1940.

Plant-Food Elements in 15 Tons of Sugar Beets

	Nitrogen	Phosphoric Acid	Potash	Total
Roots	55 lb.	22 lb.	53 lb.	130 lb.
Tops	60 lb.	23 lb.	92 lb.	175 lb.
Total	115 lb.	45 lb.	145 lb.	305 lb.

The Canada and Dominion Sugar Company has conducted analyses of beet roots and tops at harvest time, and reported their findings at two regional conventions of the A. S. S. B. T. in Detroit, 1938-1940. Stimulated by a publication of the Du Pont Company in September 1939, called "The Rate of Plant Food Absorption,"

[1]In charge and assistant, respectively, of Agricultural Research Dept., Canada and Dominion Sugar Co., Ltd., Chatham, Ont.

[2]"Facts About Sugar"—Vol. 35. September 1940, reported a yield of 45,04 long per acre with 17.94 percent sugar on 34.3 acres in California in 1939.

we undertook an introductory study of this subject for sugar beets. The publication in question dealt only with tomatoes, potatoes, corn and tobacco, drawing upon experimental data from various American journals, and experiment station reports.

Object

In this study our object was to gain further information on feeding sugar beets, from analyses of sugar beets at various stages of growth. It was an attempt to see what is in the average sugar-beet plant at "various stages" in order to get some indication of the rate of plant-food absorption during the growing season.

Plan

The plan was to utilize sugar-beet plants growing under normal Ontario conditions and select random samples whose analyses would indicate the plant-food elements taken in by the plants up to that particular stage of growth.

A commercial field in each of our factory areas was used and samples taken at about 3-week intervals. In the early stages of growth a definite length of row was taken and the data calculated on an acre basis. When the beets were of sufficient size, a definite number of beets were taken and correlated with average stand and yield per acre. The data were then calculated back to a l5-tons-per-acre crop.

Roots and tops were weighed and analyzed separately at each of 7 stages of development. The items investigated were fresh and dry weights, nitrogen, phosphoric acid, potash and calcium.

Photographs were taken of the beet plants at each of the 7 stages analyzed. and cover the normal growing period of 170 days in Ontario.

Methods

Fresh weights were taken of tared beets and tops as soon as lifted in the field and dry weights were obtained after chopping and drying in an electric oven at 65° C.

Ashing and preparation of 1he solution for analysis for P_2O_5, K_2O and CaO were made by method of C. F. Rivas, published in "Scientific Agriculture," Vol. 19, No. 4, 1938.

Analyses for nitrogen, P_2O_5, CaO and K_2O were made by the A. O. A. C. methods, 1940 edition.

Results

The analytical results of these samples, made in duplicate, were averaged for two experimental fields, one a Clyde clay and the other a Thames clay loam. Since it was impossible to analyze the same beets throughout the growing season, there is considerable variation in the contents found. The stages of growth, however, were distinct and show the relative composition of the sugar beets at approximately 3-week intervals.

Sugar beets at 7 growth stages: Stage 1, June 6—26 days; 2, June 26—46 days; 3. July 11—66 days; 4. August 12—93 days ; 5, August 29—110 days; 6, September 25—137 days; 7, October 25—167 days.

Data

The data are presented in 5 tables. Table I gives the fresh and dry weights of tops and roots at each of the 7 stages for which the length of growing season and date are given.

Tables II to V, inclusive, show the content of sugar beets at each stage, in terms of the pounds of nitrogen, phosphate, potash, and calcium in the roots and tops, with increments between stages.

The tables are paralleled with histograms which show graphically the amount of each plant-food element in root, top, and total plant at each of the stages investigated.

Table I.—Fresh and Dry Weights of Beets at Various Stages of Growth
(In tons per acre based upon harvested weight of 15 tons per acre)

Stage 0	Date May 10	Days 0	Fresh weight of beets			Dry weight of beets		
			Roots	Tops	Total	Roots	Tops	Total
1	June 6	26	0.036	0.483	0.519	0.004	0.031	0.036
2	June 26	46	0.063	0.763	0.825	0.009	0.079	0.088
3	July 16	66	0.488	2.035	2.523	0.087	0.265	0.352
4	Aug. 12	93	2.229	3.082	5.311	0.607	0.668	1.275
5	Aug. 29	110	5.288	6.002	11.340	1.117	0.881	1.998
6	Sept. 25	137	11.262	9.029	20.291	2.185	1.463	3.648
7	Oct. 25	167	15.000	11.854	26.854	3.033	1.739	4.772

Table II.—Nitrogen (N) in Sugar Beets at Various Stages of Growth
(In pounds per acre for roots and tops with increments by stages)

Stage 0	Date May 10	Days 0	Lb. in 15 tons-per-acre crop			Increments by stages		
			Roots	Tops	Total	Roots	Tops	Total
1	June 6	26	0.3	5.2	5.5			
2	June 26	46	0.4	6.4	6.8	0.1	1.2	1.3
3	July 16	66	3.1	17.9	21.0	2.7	11.5	14.2
4	Aug. 12	93	19.9	35.1	55.0	16.8	17.2	34.0
5	Aug. 29	110	29.1	42.8	71.9	9.2	7.7	16.9
6	Sept. 25	137	43.4	58.8	102.2	14.3	16.0	30.3
7	Oct. 25	167	66.0	75.9	141.9	22.6	17.1	39.7

Table III.—Phosphate (P_2O_5) in Sugar Beets at Various Stages of Growth
(In pounds per acre for roots and tops with increments by stages)

Stage	Date	Days	Lb. in 15-tons-per-acre crop			Increments by stages		
			Roots	Tops	Total	Roots	Tops	Total
0	May 10	0						
1	June 6	26	0.1	0.5	0.6			
2	June 26	46	0.1	1.0	1.1	0.0	0.5	0.5
3	July 16	66	1.3	3.7	5.0	1.2	2.7	3.9
4	Aug. 12	93	6.0	6.3	12.3	4.7	2.6	7.3
5	Aug. 29	110	9.7	12.2	21.9	3.7	5.6	9.6
6	Sept. 25	137	15.5	17.8	33.3	5.8	5.6	11.4
7	Oct. 25	167	25.4	17.2	42.6	9.9	-0.6	9.3

Table IV.--Potash (K_2O) in Sugar Beets at Various Stages of Growth
(In pounds per acre for roots and tops with increments by stages)

Stage	Date	Days	Lb. in 15-tons-per-acre crop			Increments by stages		
			Roots	Tops	Total	Roots	Tops	Total
0	May 10	0						
1	June 6	26	0.5	6.3	6.8			
2	June 26	46	0.5	7.0	7.5	0.0	0.7	0.7
3	July 16	66	2.9	15.8	18.7	2.4	8.8	11.2
4	Aug. 12	93	10.6	48.7	59.3	7.7	32.9	40.6
5	Aug. 29	110	22.3	59.3	81.6	11.7	10.6	22.3
6	Sept. 25	137	38.0	101.0	139.0	15.7	41.7	57.4
7	Oct. 25	167	105.8	74.4	180.2	67.8	26.6	41.2

Table V.—Calcium (CaO) in Sugar Beets at Various Stages of Growth
(In pounds per acre for roots and tops with increments by stages)

Stage	Date	Days	Lb. in 15-tons-per-acre crop			Increments by stages		
			Roots	Tops	Total	Roots	Tops	Total
0	May 10	0						
1	June 6	26	0.1	0.9	1.0			
2	June 26	46	0.1	2.3	2.4	0.0	1.4	1.4
3	July 16	66	0.7	6.8	7.5	0.6	4.5	5.1
4	Aug. 12	93	3.6	16.9	20.5	2.9	10.1	13.0
5	Aug. 29	110	7.5	20.9	28.4	3.9	4.0	7.9
6	Sept. 25	137	15.1	37.8	52.9	7.6	16.9	24.5
7	Oct. 25	167	22.0	49.5	71.5	6.9	11.7	18.6

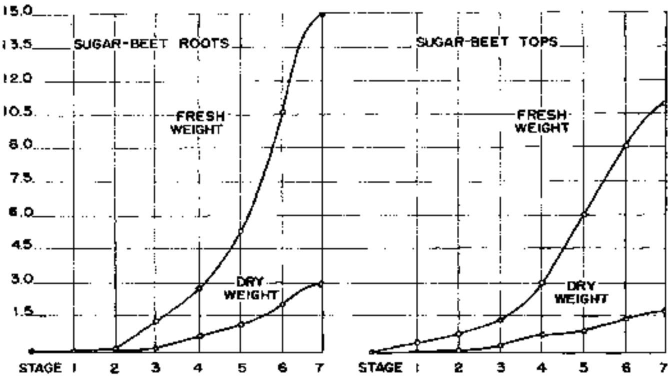
Discussion of Results

Fresh Weights.—When the sugar-beet weights are plotted against stages of growth the line connecting these points shows a close approximation to the growth curve of Mitscherlik (1). The early stages of growth were characterized by a slowly increasing rate which became a maximum in July and August. Harvest in late October apparently cut into the slackening off of growth rate, which normally follows a sigmoid curve.

The sugar-beet roots weighed less than the tops at each of the stages until mid-August, but root growth was accelerated from then on so that the roots were 26 percent heavier than the tops at harvest time. The root weight of 15.00 tons per acre had a crown and top weight of 11.83 tons after 167 days of growth.

Dry Weights.—In the first stages of growth, sugar beets have a very low dry-matter content. The analyses at different stages showed an increasing percentage of dry matter, which in roots rose from 12 to 20 percent, and in tops from 6 to 16 percent during the 7 stages of analysis. The l5-tons-per-acrc crop of beets at harvest time contained 3.038 tons of dry matter in the roots and 1.789 tons of *dry* matter in the tops, as seen in table I. The graph below shows the dry-matter stages approaching a normal growth curve in a more depressed form than those of the fresh material.

FRESH AND DRY WEIGHTS OF BEETS AT VARIOUS STAGES OF GROWTH



Nitrogen.—Nitrogen was the second largest plant-food element in the sugar beets, with 141.9 pounds per acre at harvest time. The tops contained more than half of the total nitrogen at every stage, but the root-contained nitrogen increased proportionately, as root development was rapid during the later stages of growth. At stage 7, in October, the roots contained 66.0 pounds and the tops 75.9 pounds of nitrogen.

The nitrogen content of tops, in percentage of dry matter, was almost double that of the roots at all stages, but in both roots and tops, the nitrogen percentage of dry matter dropped at later stages, so that in stage 7, at harvest, it was only half of what it had been at stage 1, near thinning time. Thus, an initial nitrogen content of 2.95 percent in the roots and 4.07 percent in the tops had decreased to 1.04 percent in the roots and 2.12 percent in the tops, at harvest.

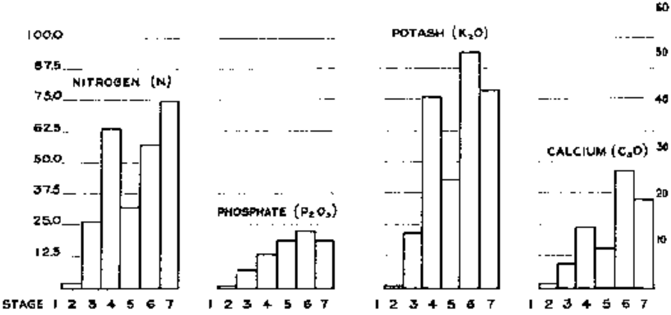
The nitrogen content of beets exceeded the potash content in July, but was relatively less at earlier and later stages. The data would indicate a need of sugar beets for available nitrogen in increasing amounts as the growing season progresses and a build-up of nitrogen in the plant especially during the rapid growing period.

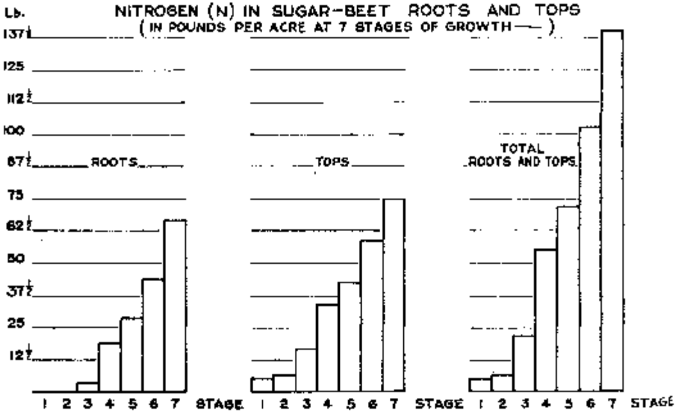
Phosphate.—Although the total amount of phosphate found in sugar beets at any stage of growth is relatively small compared to nitrogen or potash, it is utilized at all stages of growth, and totalled 42.6 pounds in a 15-tons-per-acre crop. About 60 percent of the phosphate was in the roots in the October stage, but this larger proportion was only attained in the later stages when root growth was dominant over top growth.

On a dry-matter basis, phosphate was slightly over 1 percent in the pre-thinning stage and decreased in proportion, in both root and top. until harvest time when it was under 0.5 percent of the total dry matter. Nevertheless, phosphate was taken up by the tops and roots in increasing amounts all through the season except in the final stage when the tops were partially decimated by Oercospora. In the roots. the greatest increment of phosphate was in the final stage of growth. Phosphate should be available to the beet plant all through the growing season, and be present in larger quantities toward the end of the growth period when it apparently plays a part in the maturity and keeping quality of the beets.

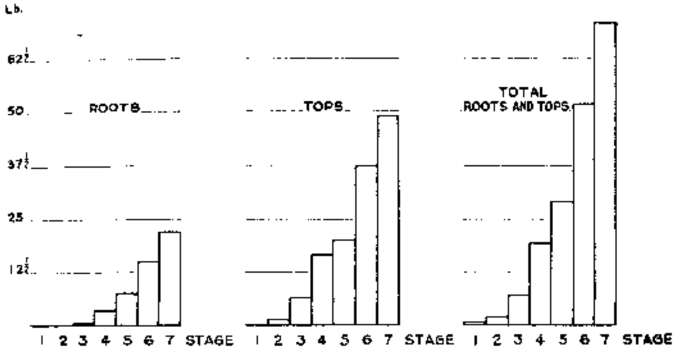
Potash.—Among the plant-food elements found in sugar beets, potash ranks highest both in percentage of dry matter and in total weight of plant. In the 15-tons-per-acre crop at harvest, the potash totalled 180.2 pounds, of which 105.8 pounds were in the roots and 74.4 pounds in the tops.

HISTOGRAMS SHOWING INCREMENTS OF NITROGEN, PHOSPHATE, POTASH. AND CALCIUM BETWEEN STAGES OF GROWTH OF SUGAR BEETS





CALCIUM (C_2O) IN SUGAR-BEET ROOTS AND TOPS
(IN POUNDS PER ACRE AT 7 STA6ES OF GROWTH)



In these analyses the potash, at all stages of growth, was very high in terms of dry matter, being over 8 percent in the seedling roots and nearly 6 percent in the seedling tops. Although the percentages, in terms of dry matter, were lower in later stages, the tops still contained over 3 percent potash at stage 6.

Potash increments were large at every stage of growth and greater than those of any other element for the same period. The drain on soil potash was particularly high for the tops after the middle of July and continued up to harvest though the last period fell off a little, probably due to Cercospora effect on the leaf tissue. The largest call for potash in the roots was in September and October.

The soils used for the sugar beets in this experiment are well supplied with potash reserves, as seen in the analyses presented below. However, the needs of the plant are so groat that adequate supplies must be assured the beets throughout the growing season. Soil analyses should go hand in hand with fertilizer analyses and give particular attention to potash.

Calcium.—Calcium is important to the sugar beet, not only in its role of giving a favorable soil reaction, but as an element of the plant itself. There were larger amounts of calcium present in the beets at all stages than phosphate and the 15-tons-per-acre crop at harvest contained 22.0 pounds of CaO in the roots and 49.5 pounds in the tops, a total of 71.5 pounds per acre of beets.

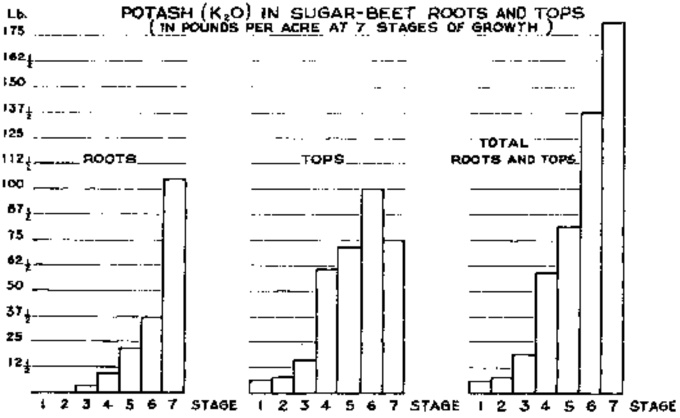
The beet seedlings contained almost 1 percent of calcium in the dry matter of the roots and 1.6 percent in the tops. In dry matter at subsequent stages the root percentages were down below 0.5 percent but in the tops the percentages stayed well above 1 percent at all stages, thereby containing nearly 50 pounds in sugar-beet tops at harvest time. Calcium is needed by the beet at all stages of growth and is taken in steadily throughout the growing season.

Magnesium.—Since sugar beets normally contain a considerable amount of magnesium, the contents of sugar beets at each stage in one series of samples were taken. Due to incompleteness of the data, they were not included in the tables, but paralleled the calcium contents to quite a degree. The magnesium content of tops was higher than the magnesium content of roots and was above 1 percent of the dry-matter weight of tops throughout most of the growing season.

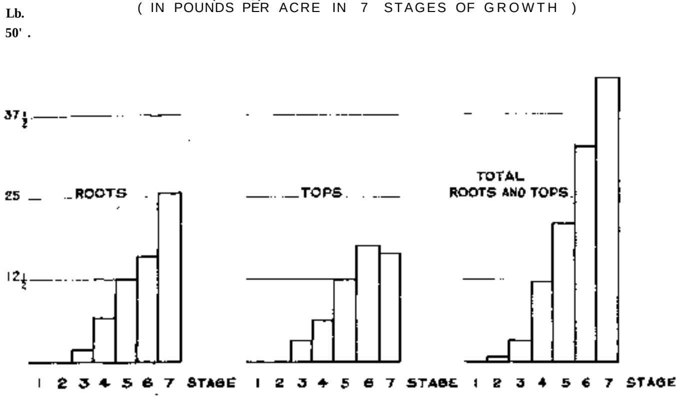
Though not as high a percentage in the roots as in the tops, there was always a considerable amount of magnesium present and it was taken up by the plant all through the growing period.

Soil Analysis

The soil type and available plant-food elements are important in the study of sugar-beet contents and in any plan to increase production levels. Further investigation may prove that the soil content of plant-food elements has much to do with the plant contents. The beets used for this investigation were taken from a series of plots on a Clyde clay and a series on Thames clay loam. Both soils

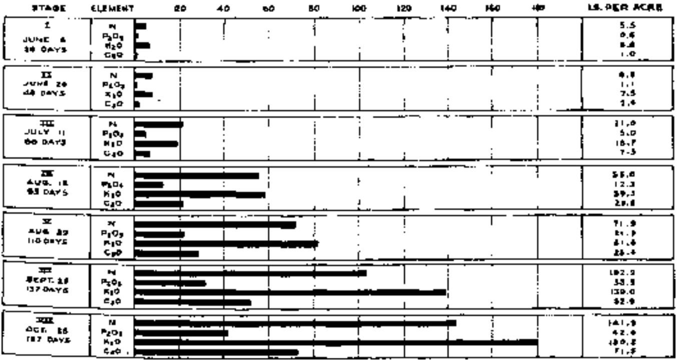


PHOSPHATE (P_2O_5) IN SUGAR-BEET ROOTS AND TOPS
(IN POUNDS PER ACRE IN 7 STAGES OF GROWTH)



are low in available phosphate, but have a relatively high potash content. Some analyses of these soil types were given in the 1940 Proceedings of the Society (2).

RELATIVE AMOUNTS OF PLANT-FOOD ELEMENTS IN SUGAR BEETS
(IN POUNDS PER ACHE OF 15-TON CROP AT T STAGES OF GROWTH)



Soil Type	pH Reaction	Percentage total nitrogen	Active organic matter	Phosphate (P_2O_5) Neubauer	Phosphate (P_2O_5) Thornton	Potash (K_2O) Neubauer	Potash (K_2O) Truog
Clyde clay	7.4	.512	0.3%	57 lb.	117 lb.	421 lb.	361 lb.
Thames clay loam	7.6	.240	3.3%	46 lb.	64 lb.	529 lb.	488 lb.

Rapid analyses tests, just prior to seeding these fields, verified the above relationship, so 200 pounds per acre of 2-12-10 were applied with the seed to the Clyde elay and 200 pounds per acre of 2-16-6 to the Thames clay loam. Phosphate applications have consistently been found to be important in these soils for increasing yields, though moisture and organic matter are undoubtedly limiting factors.

Conclusions

The limited scope of this investigation doubtless leaves many gaps in the picture of the plant-food intake of sugar beets. More frequent and wider sampling would give smoother graphs and closer correlation in growth stages. The analyses of the final stage fit in well with data published by the U. S. D. A. in 1941 on the "Mineral Composition of Crops" (3).

This experiment is of interest in the picture it gives of the sugar-beet plant at various stages of growth, and points to the need of adequate plant-food elements being available throughout the growing season.

The question of a plant taking up elements in excess of growth requirements has not been discussed, but under field conditions, where yields seldom go above 15 tons per acre, it is probably not a factor.

There is a differential call for plant-food elements in the roots and tops which changes considerably as the growing season progresses.

The sugar-beet plant requires a plentiful supply of nitrogen and potash at all stages of growth, but the presence of phosphate, calcium, and magnesium in both roots and tops is evidence of their essential part in normal development.

The data indicate a need for correlation of information on soil contents with carefully planned fertilizer treatments.

Literature Cited

1. Willcox, O. W.—The Logistic Curve of Plant Growth, Principles of Agrobiology—page 48.
2. Brown, H. D.—Applying Fertilizer to Sugar Beets in Ontario, Proceedings A. S. S. B. T. 1940—page 73.
3. Beeson, *K.* C.—The Mineral Composition of Crops, U. S. D. A. Miscellaneous Publication No. 369, March 1941.