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Yield and Nutrient Content of Sugar-Beet Tops

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WHEN SUGAR BEETS are harvested, the tops, including leaves and crowns, are removed in the operation of topping. In the majority of cases the topped portions are left in the field to be later plowed back into the soil. In some instances the tops are fed to livestock, being either pastured off of the field directly or hauled to feed lots. Recently there has been much interest among beet growers of the Red River Valley as to the feeding value of sugar-beet tops and their value as fertilizer when plowed back.

Investigations were started in 1940 to determine the influence of various fertilizers on the yield and composition of the roots and tops of sugar beets grown in the Red River Valley. The results obtained for four seasons—1942, 1943, 1944, 1945—with sugar-beet tops are reported. The experiments were conducted in cooperation with the Northwest Experiment Station and growers in Polk and Marshall counties on soils of the Fargo-Bearden soil association. Locations were selected which were representative of the sugar-beet growing area.

YIELDS OF ROOTS AND TOPS

The yields of the roots and green tops were obtained at the regular time of harvest in the latter part of September or early October. Samples of the tops were then dried to constant weight in a forced-draft oven at about 120°C. for the purpose of obtaining the dry matter content. Average yields of roots and tops for the four years, 1942 to 1945 inclusive, are given in table 1. The yields of roots were highest in 1943 and lowest in 1945. Moisture and temperature were most favorable in 1943 when the rainfall was moderate and well distributed during the growing season and the temperature above normal in July and August (tables 2 and 3). In 1945 the rainfall was not as well distributed and the season was cooler than in 1943.

The yields of both roots and tops varied widely on different locations even on the same soil type. For example, in 1943, on plots where no fertilizer was used yields of roots ranged from 12.4 to 21.1 tons per acre, and on plots treated with superphosphate the yields ranged from 13.9 to 22.7 tons. The location had a greater influence on beet yields than fertilizer treatment. This was due in large part to differences in soil fertility and to differences in soil moisture and drainage conditions.

The yields of tops varied fairly closely with the yields of roots regardless of location, fertilizer treatment, or season; that is, a large yield of roots was

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Table 1. Average Yields of Sugar-Beet Roots and Tops in the Red River Valley, 1942 to 1945 Inclusive

Year	No. of locations*	Acre yields of roots	Acre yields of tops		Dry matter content of tops	Weight of tops per ton of roots harvested		Correlation coefficients† between yields of roots and dry tops
			Green	Dry		Green	Dry	
		Tons	Tons	Tons	Per cent	Pounds	Pounds	r
1942	6	16.60	12.31	1.76	14.3	1483	212	.....
1943	10	17.65	13.83	2.24	16.2	1567	254	0.4339
1944	9	14.14	10.00	1.41	14.1	1414	199	0.6685
1945	9	11.86	8.64	1.33	15.4	1457	224	0.5583
Average	34	15.00	11.17	1.69	15.1	1489	225	.....

* From each location yields on the fertilized and unfertilized plots were averaged so that averages given for 34 locations are averages of 102 samples.

† Correlation coefficients were obtained for pairs regardless of fertilizer treatment. The numbers of pairs were 100 in 1943, 171 in 1944, and 216 in 1945.

Table 2. Rainfall in Inches During the Growing Season May 20 to September 20, 1942 to 1945 Inclusive

Year	No. of stations	May	June			July			August			September		Total
		21-31	1-10	11-20	21-30	1-10	10-20	21-31	1-10	11-20	21-31	1-10	11-20	
Polk County														
1942	5	0.55	0.20	0.45	0.75	0.92	1.03	0.75	1.35	0.51	3.69	0.19	0.33	10.72
1943	14	2.13	1.55	0.99	0.86	0.24	1.40	1.36	1.50	0.14	1.45	0.49	0.06	11.44
1944	11	1.29	1.61	1.19	1.44	1.11	0.59	0.20	4.93	0.53	3.35	0.29	0.15	16.68
1945	9	0.11	1.17	1.11	0.73	0.61	0.84	0.55	0.21	0.94	0.64	1.63	1.25	9.79
Marshall County														
1943	8	1.73	2.35	1.03	0.68	0.25	1.37	0.72	0.97	0.42	1.24	0.59	0.05	11.53
1944	7	1.23	2.87	1.12	1.55	1.07	0.23	0.36	4.52	0.47	2.50	0.26	0.08	16.26
1945	7	0.55	0.95	0.53	0.99	1.00	1.24	0.86	0.17	1.14	1.27	2.25	1.33	12.28

associated with a large yield of tops. This is shown in table 1 by the positive correlations between yields of roots and dry tops. The yields of roots were somewhat more sensitive to fertilizer treatment than yields of dry tops so that the positive correlations between yields of roots and dry tops were from fair to good instead of being higher. The correlation coefficient of 0.6685 in 1944 is significantly higher than that of 0.4339 in 1943. The high rainfall in August in 1944 probably stimulated the growth of tops so as to cause the closer correlation between the yields of roots and tops. The correlation between yields of roots and yields of green tops would be somewhat higher. There was no case in which large top growth was associated with a poor yield of roots.

The average dry matter content of the beet tops ranged from 14.1 per cent in 1944 to 16.2 per cent in 1943. This variation was probably due to differences in rainfall in the latter part of the season. In 1943 the rainfall was high enough to make for a large growth of roots and tops. In 1944 the rainfall was too high in the latter part of the season for the best growth and development of the roots. The yields were somewhat lower in 1944 than in 1943, and the top growth was more succulent.

The entire green weight of the beet plants as harvested consisted of about 58 per cent roots, 6 per cent crowns, and and 36 per cent leaves. The tops therefore made up about 42 per cent of the total green weight. The proportion of the green weight of the top to the root will vary considerably with different soil and climatic conditions. On fields where the growth is highly vegetative the weight of tops may approach the weight of roots; while on other fields where the top growth is smaller be-

Table 3. Mean Monthly Temperatures During the Growing Season, 1942 to 1945 Inclusive*

Year	May	June	July	August	September
			Polk County (Crookston)		
Normal	54.5	64.4	69.5	66.6	57.2
Departure from Normal					
1942	−3.2	−3.3	−2.2	−0.2	−4.5
1943	−3.8	−1.8	+3.0	+1.0	−3.2
1944	+2.5	−0.7	−1.7	−0.6	−1.1
1945	−7.2	−5.2	−2.6	0.0	−3.8
			Marshall County (Argyle)		
Normal	54.4	63.2	68.9	66.5	56.7
Departure from Normal					
1942	−4.2	−3.0	−3.0	−1.9	−4.7
1943	−5.1	−3.1	+2.6	+0.3	−3.6
1944	+2.1	−1.5	−3.2	−1.9	−1.0
1945	−9.7	−5.0	−3.3	−0.5	−3.8

* Climatological data—U. S. Department of Commerce, Weather Bureau.

cause of a shortage of moisture or for other reasons, the weight of tops may be only about one half the weight of the roots. For beets grown under irrigation in the western states[1] it has been found that the tops will range in weight from 30 to 70 per cent of the marketed weight of roots produced. In areas where beets are grown without irrigation the proportion of the weight of tops to roots is usually higher.

The data in table 1 show that on the average 1,489 pounds of green beet tops or 225 pounds of dry tops were harvested for each ton of roots. The yield of dry tops ranged from 10 to 12.7 per cent of the root tonnage with an average of 11.25 per cent. It is therefore considered that a conservative estimate of the yield of dry tops on any field of beets would be equal to 10 per cent of the root tonnage, or 200 pounds per ton. With a yield of 15 tons of beets the yield of dry tops would be estimated to be 1.5 tons.

EFFECT OF FERTILIZERS

Yield and Dry Matter of Tops

Nitrogen (N), phosphate (P), and potash (K) fertilizers were used in the experiments at different rates of application and in different combinations as is shown in table 4. Nitrogen was supplied in the form of sulfate of ammonia, phosphate as 43 per cent superphosphate, and potash as 60 per cent muriate of potash or its equivalent as 25 per cent manure salts or 50 per cent sulfate of potash. The phosphate was applied with a fertilizer attachment to the planter. The other fertilizers were applied on the surface with a Thompson spreader immediately following planting. Randomized block experiments were used and the data obtained were analyzed by the variance method.

With the exception of 1945, the fertilizers did not influence the yields of sugar-beet tops to any appreciable extent. Even though high yields of tops tend to be associated with high yields of roots, the yields of tops were influenced less by fertilizer treatment than the yields of roots. Consequently, the yields of dry tops per ton of roots were somewhat less where fertilizers were used than when no fertilizer was used. For the four-year period the yield of dry tops on the unfertilized plots was 11.7 per cent of the beet tonnage or 234 pounds per ton, while the yields for both the phosphate and phosphate-potash treatments were 11.0 per cent of the beet tonnage or 220 pounds (see table 1). The data for 1944 and 1945 are presented in table 4. In 1944 complete fertilizer (NPK) was the only treatment which gave an increase in yield of tops. In 1945 the phosphate treatments increased the yields of dry tops markedly, while the potash increased them slightly.

The potash treatments increased the moisture content of the tops in 1943, 1944, and 1945. In 1944 when the rainfall was relatively high in the latter part of the season, potash lowered the weight of dry tops obtained for each ton of roots harvested and significantly increased the moisture content of the roots. Potash therefore has a tendency to increase the moisture content of the

[1] Skuderna, A. W., and Sheets, E. W. "Important sugar-beet byproducts and their utilization." U.S.D.A. Bul. 1718. 1934.

Table 4. Yields and Dry Matter Contents of Sugar-Beet Tops Grown in the Red River Valley in 1944 and 1945

Fertilizer treatment†	Averages for 9 fields 1944				Averages for 9 fields 1945			
	Yields of tops		Dry matter content	Weight of dry tops per ton of beets	Yields of tops		Dry matter content	Weight of dry tops per ton of beets
	Green	Dry			Green	Dry		
	Tons	Tons	Per cent	Pounds	Tons	Tons	Per cent	Pounds
None	9.52	1.38	14.5	211	7.07	1.16	16.4	236
P	9.93	1.40	14.1	196	9.34*	1.41*	15.1*	218
2P	10.28	1.49	14.5	205	9.94*	1.54*	15.5	235
K	10.00	1.41	14.1	197	8.08*	1.26	15.6	239
2K	9.71	1.32	13.6*	182*	8.21*	1.24	15.1*	235
PK	10.07	1.39	13.8*	183*	10.20*	1.52*	14.9*	222
2(PK)	10.15	1.38	13.6*	182*	9.58*	1.37*	14.3*	207*
NPK	10.85*	1.52*	14.0*	198	10.68*	1.56*	14.6*	216
Sig. Diff. (5 per cent)	0.96	0.13	0.5	20	1.00	0.15	1.1	25

† N = 100 pounds 20 per cent sulfate of ammonia per acre.
P = 120 pounds 43 per cent superphosphate per acre.
K = 90 pounds 60 per cent muriate of potash per acre.
* Significant increase or decrease as compared to yields on unfertilized plots.

entire beet plant, and especially when used at high rates of application. This was most noticeable in 1944 when 180 pounds of muriate of potash increased the moisture content of the tops by 0.9 per cent and the roots by 1.1 per cent. The potash treatment at 90 pounds increased the moisture content slightly but not significantly. Where potash was used at the lower rate of application there was only one instance in 1944 in which the yield of dried tops fell to an appreciable extent below 10 per cent of the harvested root tonnage. Thus the amounts of potash normally included in fertilizers for sugar beets would have only a slight effect, if any, on the amounts of moisture in either roots or tops.

Nutrients and Minerals in Tops

The nutrient and mineral contents of the beet tops are presented in tables 5 and 6. It will be noted in table 5 that the season had a greater influence on the composition of the beet tops than the fertilizer treatment. In 1944 the crude protein, crude fiber, and ash were higher than in 1943. The dry matter content of the tops and the nitrogen-free extract, which includes starches, sugar, and other more soluble carbohydrates, were higher in 1943 than in 1944. The sugar content in the beet roots was about 2 per cent higher in 1943 than in 1944. In 1943, which was the season most favorable for the production of sugar beets, conditions were more suitable for the assimilation of plant nutrients and the production of carbohydrates, with the result that the plants were higher in starches and sugars and lower in proteins. The fertilizers did not have any significant influence on the nutrient content of the tops when expressed on a dry basis.

The data in table 6 show that the season was of first importance in influencing the mineral content of the tops. Potash was higher in the tops in the more favorable season of 1943 than in 1944, and phosphorus was lower. The amount of sulfur, like that of nitrogen or crude protein, was lower in the more favorable season. This was probably due to the carbohydrate content being higher. Phosphate and potash fertilizers did have some influence on the composition of the dry matter and particularly on soils where there were deficiencies in one or more of the mineral nutrients. Where no fertilizer was applied, the phosphorus content of the beet tops ranged from 0.132 to 0.275 per cent. The phosphate treatment increased the phosphorus content of the

Table 5. Nutrient Content of Sugar-Beet Tops as Influenced by Season and Fertilizer Treatment*

Fertilizer treatment†	Dry matter content of green tops	Nutrients expressed on a dry basis				
		Crude protein	Crude fat	Crude fiber	Ash	Nitrogen-free extract
	Per cent					
1943—Averages for 10 locations						
None	16.5	17.46	1.30	10.34	16.42	54.48
P	16.2	17.29	1.27	10.61	16.65	54.18
PK	15.8	16.83	1.35	11.00	15.49	55.33
Average 30 samples	16.2	17.19	1.31	10.65	16.19	54.66
1944—Averages for 6 locations						
None	14.5	20.33	1.04	11.18	17.92	49.51
P	14.1	19.55	1.00	11.41	18.05	50.00
PK	13.7	20.41	1.19	11.62	18.40	48.39
Average 18 samples	14.1	20.10	1.08	11.40	18.12	49.30

* The chemical analysis of the samples was made under the direction of Dr. W. F. Geddes, Chief of the Division of Agricultural Biochemistry.

† Fertilizer treatment:
P = 120 pounds 43 per cent superphosphate.
K = 180 pounds 60 per cent muriate of potash.

Table 6. Mineral Content of Sugar-Beet Tops as Influenced by Season and Fertilizer Treatment

Fertilizer treatment†	Mineral content expressed on a dry basis						
	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Sulfur	Chlorine
	Per cent						
1943—Averages for 6 locations							
None	2.484	0.174	6.019	1.030	1.167	0.565	0.610
P	2.531	0.205	6.020	0.921	1.056	0.564	0.600
K	2.421	0.190	6.754	0.981	1.125	0.483	1.624*
PK	2.458	0.199	6.106	0.849	1 020	0.515	1.482*
PK(MS)	2.456	0.193	6.076	0.938	1.004	0.496	2.198*
Average	2.470	0.192	6.163	0.942	1.074	0.525	.....
1944—Averages for 6 locations							
None	2.798	0.221	5.606	1.102	0.980	0.589	0.395
P	2.894	0.262*	5.591	1.121	1.051	0.616	0.267
2P	2.908	0.267*	5.505	1.157	1.034	0.615	.....
K	3.170	0.255*	6.063	1.109	1.060	0.573	.....
PK	3.022	0.260*	5.466	1.067	1.067	0.610	1.571*
PK(S)	3.074	0.251*	5.946	1.158	1.063	0.648	0.419
PK(MS)	3.055	0.264*	5.518	1.094	1.038	0.451*	2.478*
NPK	3.039	0.262*	5.800	1.066	1.014	0.586	.....
Average	2.995	0.255	5.687	1.109	1.038	0.586	.....

† Fertilizer treatment:
N = 100 pounds 20 per cent sulfate of ammonia.
P = 120 pounds 43 per cent superphosphate.
K = 180 pounds 60 per cent muriate of potash or its equivalent as 25 per cent manure salts (MS) or 50 per cent sulfate of potash (S).

* Significant increase or decrease as compared to the control.

beet tops on eight of the 12 locations, with increases ranging from 18.5 to 58.3 per cent of the control. The average increase on the 12 locations was 18.3 per cent.

The sugar-beet tops were high in potassium with percentages ranging from 3.72 to 6.61 where no fertilizer was applied. Potash fertilizers caused a slight average increase in the potassium content of the beet tops. On the location where the potassium content of the tops on the unfertilized plot was 3.72 per cent, the potash fertilizer increased the yield of roots from 13.55 to 15.18 tons per acre and the potassium content of the tops from 3.72 to 6.03 per cent.

In general the soils in the Red River Valley on which sugar beets are grown

Table 7. Composition of Sugar-Beet Tops, Alfalfa Hay, and Corn*

	Sugar beet tops			Alfalfa hay	Corn
	Green	Dry	Cured	Cured	Shelled
					Per cent
Water	84.5	0	12.0	12.0	12.0
Dry matter	15.5	100.0	88.0	88.0	88.0
Crude protein	2.613	16.86	14.84	14.31	9.65
Crude fat	0.186	1.20	1.06	1.95	3.98
Crude fiber	1.721	11.10	9.77	28.23	2.29
Nitrogen-free extract	8.308	53.60	47.17	35.43	70.70
Mineral matter	2.672	17.24	15.17	8.08	1.39
Mineral constituents:					
Nitrogen (N)	0.418	2.698	2.374	2.288	1.541
Phosphorus (P)	0.034	0.221	0.194	0.204	0.278
Potassium (K)	0.899	5.801	5.105	1.966	0.328
Calcium (Ca)	0.157	1.015	0.893	1.392	0.010
Magnesium (Mg)	0.165	1.062	0.935	.....	.....
Sulfur (S)	0.089	0.577	0.508	.....	.....

* Sugar beet tops—averages for 36 samples grown in the Red River Valley in 1943 and 1944. Alfalfa hay and corn values taken from Henry and Morrison, "Feeds and Feeding," Twentieth edition, and converted to 12 per cent moisture for comparison.

are well supplied with nitrogen, lime, and magnesia. The results given in table 6 show that the fertilizer treatments did not influence the nitrogen, calcium, and magnesium content of the beet tops to any appreciable extent. Where fertilizers containing chlorides were used, there were marked increases in the chlorine content of the tops. The manure salts treatment was about twice as high in chlorides as the muriate of potash treatment. The tops from the manure salts treatment were significantly higher in chlorine than those grown on the muriate of potash treatment. Potash used in the form of sulfate had no influence on the chlorine content of the tops but increased the sulfur content slightly. The manure salts treatment lowered the sulfur content significantly, indicating that a high content of chlorides in the soil tends to depress the absorption of sulfates by the plant.

FEEDING VALUE OF TOPS

A comparison of the composition of sugar-beet tops, alfalfa hay, and shelled corn is given in table 7. Beet tops are about equal to alfalfa hay in protein and are between alfalfa hay and corn in nitrogen-free extract. Beet tops are particularly high in mineral matter. The analysis would indicate that well-cured beet tops should slightly exceed alfalfa hay in feeding value.

Maynard[2] reported that carefully cured tops from a ton of beet roots should have a potential fattening value equivalent to 143 pounds of corn or to 229 pounds of alfalfa hay.

The feeding value of a ton of dried beet tops grown in the Red River Valley is approximately equivalent to a ton of alfalfa hay or 24.6 bushels of corn. With the average acre yield of 15 tons of roots, the tops would be equivalent in feeding value to 1.5 tons of alfalfa hay or 36.9 bushels of corn.

FERTILIZER VALUE OF TOPS

The quantities and values of the fertilizer constituents in sugar-beet tops are given in table 8. These values represent the extent to which the soil has been depleted of its nitrogen, phosphoric acid, and potash when sugar-beet tops are taken from the farm. The nitrogen is equivalent to the amount contained in 400 pounds of 20 per cent sulfate of ammonia and the potash to 350 pounds of 60 per cent muriate of potash. Sugar-beet tops

[2] Maynard, E. J. "The feed replacement values of sugar beet by-products." *Proc. Amer. Soc. Sugar Beet Tech.* 1944: 134-140.

Table 8. Quantities of Fertilizer Constituents in Sugar-Beet Tops*

	Pounds per ton of roots harvested (200 pounds dry tops)	Pounds per acre of 15 tons of roots harvested (3,000 pounds dry tops)	Value per acre†
	Pounds	Pounds	
Nitrogen (N)	5.4	81.0	$ 9.32
Phosphoric acid (P_2O_5)	1.1	16.5	1.07
Potash (K_2O)	14.0	210.0	11.55
			$21.94

* Calculations are based on the chemical composition of beet tops given in table 7 and on the averages for four years, from 1942 to 1945, given in table 1.

† Calculations are based on the following present prices of fertilizer constituents: $0.115 per pound for N, $.065 per pound for P_2O_5, and $.055 per pound for K_2O.

therefore have a high manurial value, amounting at present fertilizer prices to about $22.00 per acre, which should be taken into consideration whenever they are removed from the farm. When sugar-beet tops are fed on the farm, a large part of the nutrients may be returned to the soil if the manure is properly handled.

SUMMARY

The green weight of sugar-beet tops grown in the Red River Valley was about 75 per cent of the weight of the roots. On a dry basis the yield of tops ranged from 10 to 12.7 per cent of the root tonnage. It is therefore considered that 10 per cent of the root tonnage is a conservative estimate of dry tops. Thus for each ton of roots there will be approximately 200 pounds of dry tops. The percentage of dried tops was little affected by fertilizer treatment.

Soil and climatic conditions had a marked influence on the yield and composition of sugar-beet tops. For the two seasons in which the beet tops were analyzed, the tops were higher in dry matter and nitrogen-free extract and lower in protein in the season when weather conditions were more favorable for the growth of the crop.

Fertilizers had a somewhat greater influence on the yield of roots than on the yield of tops, but high yields of tops were generally associated with high yields of roots. The application of fertilizers containing relatively large amounts of potash caused some increase in the moisture content of both roots and tops of sugar beets. When applied at rates commonly used by growers, there was only a slight increase in the moisture content.

Phosphate and potash fertilizers had some influence on the composition of the dry matter of sugar-beet tops, particularly on soils where there were deficiencies of these minerals. Treatment with phosphate fertilizers substantially increased the phosphorus content of dried tops, and the inclusion of potash in the fertilizer caused a slight average increase in the potassium content. The fertilizers did not significantly influence the amounts of other constituents except chlorine in the tops. Fertilizers containing chlorides caused marked increases in the chlorine content of the beet tops.

As a feed sugar-beet tops are high in crude protein and in mineral matter. The composition of cured sugar-beet tops and alfalfa hay would indicate that beet tops are slightly superior to alfalfa hay as a feed. Feeding tests have shown them to be about equal to alfalfa hay.

Sugar-beet tops have considerable value as fertilizer because of their high content of minerals, particularly nitrogen and potassium. At present prices the value of the fertilizer elements contained in the tops from an average acre is about $22.00.