

Pre-Harvest Sampling for Estimating Commercial Production By a Randomized Method— Nine Years' Results for Great Western Sugar Company Territory

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Accurate pre-harvest estimates of the tonnage and sugar content of the sugar beet crop are highly important to the management of a beet-sugar company.

A scheme was devised and used in 1941 whereby pre-harvest samples selected at random were taken in an attempt to provide accurate pre-harvest estimates for both tonnage and sugar content. Results for this one year-indicated considerable improvement in precision over previous methods used. This scheme, with slight changes, has been used continuously since that time. The method used in 1944³ and later years was similar in most respects to the original scheme except for a geographic stratification of each factory district into receiving-station districts.

The scheme was intended to provide a considerable degree of accuracy for each factory acreage as a unit.

Results for 1941-49

Results are presented here only for the Colorado and Nebraska districts, since records are not complete for other districts for all 9 years during which this method has been used.

The final yields in tons of beets per acre and sugar percentage for the contracts sampled compared with final district averages for Colorado and Nebraska, 1941-49, are presented in Table 1. Also included is the range of differences obtained for the same comparison at each of the factories included in each district, the number of factories being included in the table.

The average percentage of sugar for the contracts sampled agrees very closely with the district averages. However, the district averages for tons of beets per acre are slightly but consistently above the yields obtained for the contracts sampled, although both **plus** and minus fluctuations have resulted for individual factory averages. The largest difference of +1.09 tons (one Nebraska factory, 1946) is not so large as the error of ± 1.58 tons, which was obtained at the 5% level of significance for the 1941 data.

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² Brewbaker, H. E., and Bush, H. L. Pre-harvest estimate of yield and sugar percentage based on random sampling technique. Proc. Amer. Soc. Sug. Beet Tech., 184-196, 1942.

³ Brewbaker, H. E., and Bush, H. L. Four years' results of pre-harvest sampling in estimating yield and sugar percentage. Proc. Amer. Soc. Sug. Beet Tech., 141-153, 1946.

TABLE 1. Final yield in tons beets per acre and percentage of sugar as averages for contracts sampled compared with final harvested averages for the Colorado and Nebraska Districts, 1941-49.

Year	No. of Contracts	Contract Final	Tons Beets per Acre			Contract Final	% Sugar		(c) Range of Diff.
			Dist. Ave.	Diff.	(c) Range of Diff.		Dist. Ave.	Diff.	
Colorado (a)									
1941	1,057	14.78	14.79	+01	- .74 to + .41	16.0	16.0	0	- .2 to + .2
1942	1,715	11.76	12.00	+ .24	- .24 to + .51	15.0	15.1	+ .1	- .1 to + .4
1943	1,198	12.54	12.82	+ .28	- .47 to + .61	16.5	16.5	0	- .1 to + .3
1944	1,087	12.46	12.64	+ .18	- .12 to + .91	17.6	17.6	0	- .2 to + .1
1945	1,416	12.01	12.16	+ .15	- .63 to + .53	16.1	16.2	+ .1	- .1 to + .3
1946	1,444	12.75	13.04	+ .29	- .89 to + .77	14.7	14.8	+ .1	- .1 to + .5
1947	1,681	15.16	15.28	+ .12	- .46 to + .70	15.8	15.8	0	- .2 to + .1
1948	966	13.69	13.74	+ .05	- .40 to + .65	15.0	15.0	0	- .1 to + .1
1949	1,119	16.43	16.49	+ .06	- .87 to + .64	17.0	17.0	0	- .1 to + .1
Nebraska (b)									
1941	180	16.26	16.28	+ .02	- .13 to + .26	16.5	16.4	- .1	- .2 to + .1
1942	626	12.05	12.32	+ .27	- .42 to + .49	14.3	14.4	+ .1	- .1 to + .3
1943	391	12.11	12.59	+ .48	- .69 to + .93	16.3	16.3	0	- .1 to + .1
1944	418	10.37	10.76	+ .39	+ .06 to + .76	16.7	16.9	+ .2	- .2 to + .2
1945	473	10.74	10.82	+ .08	- .14 to + .29	15.2	15.2	0	- .2 to + .4
1946	450	14.24	14.59	+ .35	- .18 to + 1.09	15.4	15.3	- .1	- .3 to + .1
1947	526	12.07	12.17	+ .10	- .27 to + .32	15.8	15.8	0	- .2 to + .2
1948	381	11.84	12.01	+ .17	- .06 to + .41	14.1	14.1	0	- .1 to + .1
1949	323	15.24	15.45	+ .21	- .33 to + .67	16.2	16.3	+ .1	- .1 to + .1

Note: All averages have been weighted in accordance with the number of contracts sampled in each factory district.

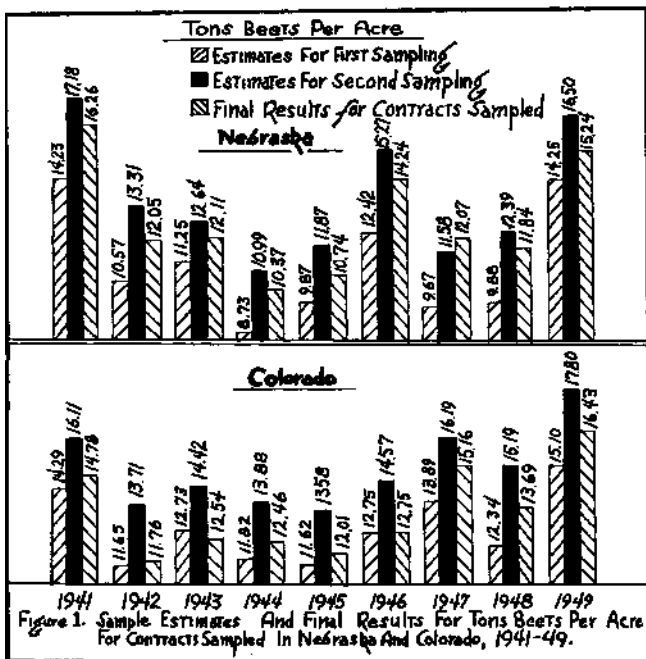
(a) 12 factories

(b) 3 factories, 1941

6 factories, 1942-47

5 factories, 1948-49

(c) Range of maximum differences between district averages and final contract yields as obtained from individual factory averages.



The arithmetical averages for both tons of beets per acre and percentage of sugar (Table 1) for the contracts sampled do not take into account the varying acreages involved in each contract. It is probable that the average tonnage obtained by weighting the yield for each contract by its appropriate acreage would tend to correct for the discrepancy between averages for contracts sampled and district averages. However, since no consideration of this point has been made in the past, data are not readily available except for one factory district (Loveland, Colorado) in 1949, which are suggestive of the possibilities for improving predictions by this method of calculations. These results are as follows:

Arithmetical Average.....	16.87 tons per acre
Weighted Average.....	17.45 tons per acre
Final Factory Average.....	17.51 tons per acre

Other suggestions were made³ as possibilities for overcoming this bias. However, the information as now obtained has proved to be sufficiently accurate as a basis for making predictions to satisfy practical requirements.

The average indicated tonnage for each of the sampling dates, the first about September 1 and the second two weeks later, along with the average tonnage for the contracts sampled, are presented in Figure 1.

TABLE 2. Percentage increases or decreases for yield of roots, comparing sampling estimates with final yields of the contracts sampled.

Year	Colorado			Nebraska		
	Increase 1st to 2nd Sampling	Increase 1st Samp. to Harvest	Loss 2nd Samp. to Harvest	Increase 1st to 2nd Sampling	Increase 1st Samp. to Harvest	Loss 2nd Samp. to Harvest
1941	12.74	3.43	8.26	20.73	14.27	5.36
1942	17.68	.86	14.30	25.92	14.00	9.47
1943	13.28	— 1.49	13.04	12.36	7.64	4.19
1944	17.43	5.41	10.23	25.89	18.79	5.64
1945	16.87	3.36	11.56	20.26	8.81	9.52
1946	14.27	0	12.49	22.95	14.65	6.75
1947	16.56	9.14	6.36	19.75	24.82	+ 4.23
1948	23.10	10.94	9.87	25.40	19.84	4.44
1949	17.88	10.88	7.70	15.79	6.95	7.64
Mean	16.65	4.73	10.42	21.01	14.42	5.42

As indicated in Figure 1 and presented as percentage increments in Table 2, there has been considerably more growth of beets after September 1 in Nebraska than in Colorado, the increases expressed in nine-year averages from first to second sampling dates being 16.65 and 21.01 percent for Colorado and Nebraska, respectively, with increases of 4.73 and 14.42 percent from first sampling to final harvest for the same respective comparison.

There are indicated losses of 10.42 percent and 5.42 percent (Table 2) for Colorado and Nebraska, respectively, comparing the harvested final yield with that indicated at the time of second sampling. This drop is quite consistent, with the exception of 1947 in Nebraska, when there was an indicated gain of 4.23 percent in yield of beets for the same comparison. Also, as previously indicated,³ this does not represent the entire loss, since there is continued development on some, if not all, fields after the second sampling. The source of these losses was discussed in that paper.

These percentage figures may be used, either individually or in combination, to predict yields for any year. The accuracy of the predictions will, of course, increase as yearly results are accumulated and must be accompanied by a careful consideration of the local conditions affecting the growth of the crop.

The percentage of sugar has also shown a consistently more rapid increase in Nebraska than in Colorado after September 1 as indicated in Figure 2, the results being presented in terms of percentage increase increments in Table 3.

TABLE 3. Percentage of sugar expressed in terms of percentage increase between sampling dates and final results for contracts sampled.

Year	Colorado Increase			Nebraska Increase		
	1st to 2nd Sampling	1st Samp. to Harvest	2nd Samp. to Harvest	1st to 2nd Sampling	1st Samp. to Harvest	2nd Samp. to Harvest
1941	8.73	19.40	11.51	7.35	21.32	13.01
1942	7.14	19.05	11.11	8.40	20.17	10.85
1943	13.28	28.91	15.79	21.37	39.52	14.79
1944	15.75	36.58	19.73	23.42	50.45	21.90
1945	15.20	28.89	11.81	18.53	34.51	13.43
1946	11.50	30.09	16.67	14.66	32.75	15.79
1947	5.43	22.48	16.18	11.21	36.21	22.48
1948	10.66	22.95	11.11	15.09	33.02	15.57
1949	12.03	27.82	14.09	13.60	30.40	14.79
Mean	10.52	26.45	14.00	14.85	33.13	15.85

The increases, based on a nine-year average, from first to second sampling are 10.52 and 14.85 percent for Colorado and Nebraska, respectively, while the increases from first sampling to harvest are 26.45 and 33.13 percent for the same respective comparisons. The increases from second sampling to harvest are more nearly alike in the two states, being respectively 14.00 and 15.85 percent. These average increase values may be used in predicting sugar percentage in a manner similar to that used in predicting beet tonnage.

As an indication of the expected accuracy of future predictions, theoretical estimates based on the sampling results for the past 9 years, and using

TABLE 4. Harvested average tons beets per acre compared with managers' estimates and yields estimated by pre-harvest samples.

Year	Managers' Estimate Aug. 31	Estimated (a)		Estimated (b)		Harvested District Average	Differences		
		Yield 1st Sample	Yield from 1st Samp.	Yield 2nd Sample	Yield from 2nd Samp.		Harv. minus Mgrs. Est.	Harv. minus 1st Samp.	Harv. minus 2nd Samp.
Colorado									
1941	14.81	14.29	14.97	16.11	14.43	14.79	-0.02	-0.18	+0.36
1942	13.85	11.65	12.20	13.71	12.28	12.00	-1.85	-0.20	-0.28
1943	13.92	12.73	13.33	14.42	12.92	12.82	-1.10	-0.51	-0.10
1944	12.57	11.82	12.38	13.88	12.43	12.64	+0.07	+0.26	+0.21
1945	13.31	11.62	12.17	13.58	12.16	12.16	-1.15	-0.01	0
1946	12.57	12.75	13.35	14.57	13.05	13.04	+0.47	-0.31	-0.01
1947	13.72	13.89	14.55	16.19	14.50	15.28	+1.56	+0.73	+0.78
1948	13.14	12.34	12.92	15.19	13.61	13.74	-0.60	+0.82	-0.13
1949	14.68	15.10	15.81	17.80	15.95	16.49	+1.81	+0.68	+0.54
Nebraska									
1941	15.19	14.23	16.28	17.18	16.25	16.28	+1.09	0	+0.03
1942	14.16	10.57	12.09	13.31	12.59	12.32	-1.84	+0.23	-0.27
1943	14.60	11.25	12.87	12.64	11.95	12.39	-2.21	-0.48	+0.44
1944	12.10	8.73	9.99	10.99	10.39	10.76	-1.34	+0.77	-1.37
1945	12.40	9.87	11.29	11.87	11.23	10.82	-1.58	-0.47	-0.41
1946	12.37	12.42	14.21	15.27	14.44	14.59	+2.22	+0.38	+0.15
1947	11.80	9.67	11.06	11.58	10.95	12.17	+0.37	+1.11	+1.22
1948	13.28	9.88	11.30	12.39	11.72	12.01	+1.27	+0.71	+0.29
1949	14.26	14.25	16.30	16.50	15.61	15.45	+1.19	-0.85	-0.16

Note: All averages were weighted on the basis of the number of contracts sampled in each factory district.

(a) Tonnage indicated by first sampling increased by 4.73 and 14.42 percent for Colorado and Nebraska, respectively.

(b) Tonnage indicated by second sampling decreased by 10.42 and 5.42 percent for Colorado and Nebraska, respectively.

the mean nine-year increase in tonnage of 4.73 percent from first sampling to harvest and the decrease of 10.42 per cent (Table 2) from the second sampling to harvest for Colorado, and 14.42 and 5.42 percent for the same respective comparisons in Nebraska, are presented in Table 4 along with factory managers' estimates based on the general appearance of the beet crop as made on August 31, a few days before the first pre-harvest samples were taken.



In general, the estimates, based on either the first or second sampling, resulted in estimated tonnages which more nearly approached actual yields than did the managers' estimates. The differences between estimated yields, calculated from pre-harvest samples, and tonnage actually harvested range from -0.51 to $+0.82$ tons per acre for the first sampling date and from -0.28 to $+0.78$ tons per acre for the second sampling date, and the range in differences between the managers' estimates and the final yields is -1.85 to

+1.81 tons per acre for Colorado. Similarly, differences for Nebraska are $-.85$ to $+1.11$ and $-.41$ to $+1.22$ tons per acre for the two respective samplings and -2.21 to $+2.22$ tons per acre for managers' estimates.

It is likewise possible to predict final sugar content in this same manner with greater accuracy than was possible by previous methods.

Summary and Conclusions

1. A scheme for random sampling the sugar beet acreage to aid in making predictions as to the expected yield and sugar content is discussed, using data resulting from 9 years' experience in the Colorado and Nebraska districts of The Great Western Sugar Company.

2. The fields sampled were found to yield, as an average for all factories within a district, slightly below the district average in tons of beets per acre, but the sugar content was essentially the same for both contracts sampled and district averages. Results are presented which indicate that a weighted average for the yields of the contracts sampled, based on the acreage in each contract, might have resulted in a closer agreement with district averages than do the results for tons of beets per acre based on arithmetical averages of all contracts sampled without regard for size of field.

3. There is considerably more increase in both size of beets and sugar content after the first sampling (September 1) in Nebraska than in Colorado. A loss in tonnage harvested from tonnage indicated at the second sampling is shown for both the Colorado and Nebraska districts, this loss being lower in Nebraska than in Colorado.

4. Theoretical estimates of the yield in tons per acre based on the nine-year results are presented in comparison with factory manager's estimates for each year. The estimated yields from pre-harvest samples agree more closely with actual tonnages, as harvested, than do the managers' estimates.