Performance of Sugar Beet Hybrids at Different Harvest Dates[1]

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A 3-year study was conducted to determine the response of single cross sugar beet hybrids to time of harvest at Fort Collins, Colorado. Our purpose was to determine if certain hybrid genotypes had sufficiently high yield and quality to permit them to be harvested 2 to 4 weeks earlier than normal. An early harvest of acreage planted for that specific purpose would allow beet sugar factories, in summer crop regions, to commence operations earlier than normal. The advantages of an extended campaign are many, both for the producer and processor.

Materials and Methods

During the 3-year experiment, we compared 17 single cross hybrids and a commercial check for root yield, sucrose percentage and percentage apparent purity. Four F_1 hybrids (half sibs) and the check (A56-3) were included in all three years. One hybrid was included in both 1961 and 1962, one in both 1961 and 1963, eight in 1961 only, and three in 1963 only. In choosing the hybrids quality was of primary interest. Little attention was given to high combining ability for yield, but high combining ability for sucrose content was given some consideration. All the parental inbreds were highly homozygous. The check was an open-pollinated variety adapted to northern Colorado. The planting dates were April 20, 12 and 8 in 1961, 1962 and 1963, and the 3 harvest dates each year were around September 15, October 1 and October 15 (exact dates are shown in the mean tables). The experiments were grown under irrigation at the Colorado State University Agronomy Research Center, Fort Collins, Colorado, where the average growing season is 145 days. The two center rows were harvested from four row plots 20-feet long. There were 22 inches between rows and 10 inches between plants within rows.

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A split-plot design was used each year. Dates of harvest were main plots, for convenience in harvesting and populations were sub plots. The analysis over years was made as a split-split-plot. Years were main plots, except that replicates had no identity between years. Thus the usual error *a* of a split-plot was replicates within years. There were 10 replications each year. Data were obtained for weight of roots per plot and percentage sucrose in all 3 years, and on percentage apparent purity in 1961 and 1962. Thin juice samples for apparent purity determinations were prepared according to Brown and Serro (1).

Results and Discussion

The population means for weight of roots per plot for the 3 harvest dates of 1961, 1962 and 1963, are listed in Table 1. For the years 1961 and 1963, the average weight of roots per plot did not differ materially for the early and late harvests. However, they did differ materially for these dates in 1962. In 1962, there was a decided increase in yield from September 12 to October 1, with no further increase to October 15. For 1961, there was essentially no increase in weight after September 14. In 1963, a general but not significant increase was noted from September 16 to October 14. Differences in climatic conditions between the 3 years could have accounted for this interaction which occurred between dates of harvest and years; however, no obvious relation with available climatological data could be detected.

Analyses of the data were made over years using the five populations common to all years. Within-year analyses were also made but are not shown.

Some of the differences between means for weight of roots per plot were highly significant for populations, dates of harvest and years (Table 2). The significant interactions were years × populations and years × dates of harvest. By contrast, the interactions of populations × dates of harvest, and populations × dates of harvest × years, were not significant. Neither were the populations × dates of harvest interactions significant for the three within-year analyses.

It is of considerable interest that the interactions of populations × dates of harvest, and populations × dates of harvest × years, are relatively unimportant. This indicates that the differences between the root yields for all populations are comparable for each of the 3 harvest dates in all years. Further, one date of harvest for any one of the 3 years would have given reliable information on the differences between populations for weight of roots. This finding is of particular importance to research work involving different varieties or populations, because

Table 1.—Means for weight of roots per plot of populations for the three dates of harvest during 1961, 1962 and 1963.[1]

Population	Years and dates of harvest: 1961				1962				1963				Grand mean
	9/14	10/3	10/16	Mean	9/12	10/1	10/15	Mean	9/16	9/30	10/14	Mean	
	Kg	Kg	Kg	Kg	Kg	Kg	Kg	Kg	Kg	Kg	Kg	Kg	Kg
52-305CMS × 52-430,F_1	5.69	5.56	5.86	5.70	9.58	11.24	10.76	10.53	7.02	7.08	7.01	7.04	7.76
52-430 × 52-307,F_1	8.81	8.70	8.91	8.81	11.30	12.05	12.45	11.93	15.18	14.27	16.50	15.32	12.02
52-430 × 54-565,F_1	5.56	6.27	6.18	6.00	8.72	10.68	11.16	10.19	13.21	14.25	14.16	13.87	10.02
52-430 × 54-346,F_1	6.88	6.92	6.70	6.83	9.28	10.52	10.16	9.99	13.08	14.23	13.94	13.75	10.19
A56-3 (check)	9.43	10.02	9.96	9.80	11.88	13.62	12.82	12.77	16.96	16.85	18.22	17.34	13.31
Mean and grand mean (5 common populations)	7.27	7.49	7.52	7.43	10.15	11.62	11.17	11.08	13.09	13.34	13.97	13.46	10.66
52-430 × 52-408,F_1	8.89	9.32	9.36	9.19	12.13	13.32	12.46	12.61					
52-305CMS × 52-407,F_1	6.70	6.89	7.19	6.93					14.97	14.81	15.81	15.20	
52-305CMS × 52-307,F_1	7.11	8.01	7.28	7.47									
52-430 × 54-520,F_1	6.95	7.06	6.61	6.87									
52-305CMS × 54-520,F_1	6.95	7.18	7.03	7.05									
52-305CMS × 54-565,F_1	5.88	6.42	6.63	6.31									
52-305CMS × 54-458,F_1	6.24	6.44	7.02	6.57									
52-305CMS × 54-346,F_1	6.11	6.31	6.52	6.31									
52-305CMS × 34,F_1	7.50	7.69	7.79	7.66									
54-565 × 52-407,F_1	6.69	6.76	7.64	7.03									
52-305CMS × 52-208,F_1									11.64	11.10	11.83	11.52	
NB1 CMS × 52-430,F_1									13.94	14.68	16.40	15.01	
F60-561 CMS × 52-208,F_1									14.46	14.96	15.96	15.13	

[1] Among the 5 common populations, the standard error for dates within each population each year is 0.40.

the early harvesting of some experiments increases the amount of material that can be handled and also lowers the cost. Further research, including more populations and years, is necessary before broad generalizations are justified.

The significant population × year interaction can be largely attributed to 52-305CMS × 52-430,F, in 1963. The years can be ranked in the order of increasing root yield from low in 1961, medium in 1962 and high in 1963. This is generally true for all populations except for this hybrid which for some reason had a very low yield in 1963, relative to other populations that year.

All sucrose means are presented in Table 3. The analysis of variance for percentage sucrose of five populations for 3 dates of harvest over a period of 3 years is included in Table 2. The results of this analysis are essentially the same as for weight of roots per plot, the exception being that the interaction of populations × dates of harvest × years is significant at the 5% level. This interaction, if supported by further research and correlated with weather conditions, is economically important in that maximum sucrose is reached at an earlier date in some years, after which some populations decline in sucrose content.

Another interaction of interest is dates of harvest × years. For the years 1961 and 1963, there was a consistent increase in percentage sucrose from the early through the middle to the late harvest (Table 3). However, for 1962, there was no material difference in percentage sucrose for the October 1 and October 15 harvest dates. This was true for all populations, as well as for the average of all common populations. This indicates that under certain conditions, sucrose content continues to increase

Table 2.—Analysis of variance for root yield, percentage sucrose and percentage apparent purity of 5 populations for 3 dates of harvest during 1961, 1962 and 1963.

Variation	Root weight		Sucrose	Purity*	
due to:	D F	Mean square	Mean square	D F	Mean square
Years	2	1385.4101**	148.9611**	1	5.14
Replications within years (Error a)	27	4.2806	4.1603	18	5.07
Dates	2	27.6370**	129.2491**	2	2.09
D × Y	4	8.0400**	13.7500**	2	7.26
Error b	54	1.5062	2.0298	36	7.27
Populations	4	403.4770**	42.6405**	4	40.90**
P × D	8	2.9014	0.6240	8	3.63*
P × Y	8	9.4024**	5.0250**	4	8 02**
P × D × Y	16	1.4888	0.7050*	8	1.54
Error c	324	1.6156	0.3885	216	1.66

* Significant at the 5% level.

** Significant at the 1% level.

Table 3.—Means for percentage sucrose of populations for the three dates of harvest during 1961, 1962 and 1963.[1]

Population	Years and dates of harvest												Grand mean
	1961				1962				1963				
	9/14	10/3	10/16	Mean	9/12	10/1	10/15	Mean	9/16	9/30	10/14	Mean	
	%	%	%	%	%	%	%	%	%	%	%	%	%
52-305CMS × 52-430,F_1	14.3	15.5	17.6	15.8	16.8	18.1	18.2	17.7	15.4	15.5	16.4	15.8	16.4
52-430 × 52-307,F_1	13.7	15.1	16.9	15.2	16.5	18.1	17.8	17.5	15.7	16.4	17.1	16.4	16.4
52-430 × 54-565,F_1	15.5	16.0	17.3	16.3	16.8	18.0	17.7	17.5	16.2	16.7	18.1	17.0	16.9
52-430 × 54-346,F_1	14.6	16.3	17.7	16.2	17.0	18.4	18.0	17.8	16.3	17.2	18.1	17.2	17.1
A56-3 (check)	12.5	14.2	15.2	14.0	15.9	17.3	17.3	16.8	14.5	15.1	16.0	15.2	15.3
Mean and grand mean (5 common populations)	14.1	15.4	16.9	15.5	16.6	18.0	17.8	17.5	15.6	16.2	17.1	16.3	16.4
52-430 × 52-408,F_1	14.4	15.5	16.7	15.5	16.6	17.8	18.0	17.5					
52-305CMS × 52-407,F_1	13.3	14.4	16.4	14.7					14.1	14.5	15.0	14.5	
52-305CMS × 52-307,F_1	12.9	14.8	16.2	14.6									
52-430 × 54-520,F_1	14.2	15.8	17.0	15.7									
52-305CMS ×54-520,F_1	14.1	15.2	16.6	15.3									
52-305CMS × 54-565,F_1	14.6	16.2	17.4	16.1									
52-305CMS × 54-458,F_1	13.6	14.6	16.2	14.8									
52-305CMS × 54-346,F_1	14.0	15.6	17.1	15.6									
52-305CMS × 34,F_1	13.4	15.4	16.8	15.2									
54-565 × 52-407,F_1	13.6	14.6	16.2	14.8									
52-305CMS × 52-208,F_1									16.1	16.6	17.8	16.8	
NB1 CMS × 52-430,F_1									16.0	16.5	17.4	16.6	
F60-561 CMS × 52-208,F_1									15.9	16.3	17.0	16.4	

[1] Among the 5 common populations, the standard error for dates within each population each year is 0.20.

to a late date; while for years, such as 1962, maximum sucrose content may occur 2 weeks earlier. Better knowledge of this reaction of the beet plant to local weather could lead to recommendations for early harvest in some years, late harvest in others. This could also be related to variety, as indicated by the populations × dates of harvest × years interaction. A breeding program could perhaps take advantage of this early high sucrose in some genotypes, to develop varieties which could be harvested earlier consistently.

The significant population × year interaction for sucrose can again be attributed to 52-305CMS × 52-430,F_1 which in 1963 failed to respond greatly to the later harvest dates, similar to root yield.

The lack of interaction between populations and dates of harvest means that population differences are very similar for any date. Reliable information on population differences could have been obtained from any one date of harvest, even though estimates of population means were different for the different dates. This information, along with similar results for weight of roots, makes early harvest feasible for many research applications.

Results were somewhat different for percentage apparent purity, as shown by the means in Table 4 and the analysis of variance in Table 2. The effects of years and harvest dates were not significant; neither were the interactions of years × harvest dates and populations × years × harvest dates. Again, early harvest to expedite research efforts would be feasible, since nearly maximum purity is obtained by September 15. This agrees with the report by Payne et al. (2), and Powers and Payne (3), that the levels of nitrogen, potassium and sodium are not significantly affected by date of harvest. It follows that if the thin juice impurity components are the same at various dates of harvest, the apparent purity percentage would be unrelated to dates of harvest.

For percentage purity, the effects of populations and the interaction of years × populations are significant at the 1% level. The populations, common to both years, retained the same rank but in 1961 the range was much greater. The populations 52-305CMS × 52-430,F_1 and A56-3 were much lower than the others in 1961, whereas in 1962 all populations attained a high uniform level of percentage purity.

The date of harvest × population interaction was significant at the 5% level due to 52-430 × 54-346,F_1 which continued to

Table 4.—Means for percentage apparent purity of populations for the three dates of harvest during 1961 and 1962.[1]

Population	Years and dates of harvest								Grand mean
	1961				1962				
	9/14	10/3	10/16	Mean	9/12	10/1	10/15	Mean	
	%	%	%	%	%	%	%	%	%
52-305CMS × 52-430,F1	94.1	93.3	93.7	93.7	94.3	95.1	94.4	94.6	94.1
52-430 × 52-307,F1	94.7	95.1	95.3	95.0	94.5	95.5	94.9	95.0	95.0
52-430 × 54-565,F1	95.6	95.3	95.9	95.6	95.4	95.4	94.3	95.0	95.3
52-430 × 54-346,F1	95.2	95.6	96.3	95.7	94.4	95.9	96.5	95.6	95.7
A56-3 (check)	93.7	92.7	92.9	93.1	94.0	94.5	94.3	94.4	93.7
Mean and grand mean (5 common populations)	94.7	94.4	94.8	94.6	94.5	95.3	94.9	94.9	94.8
52-430 × 52-408,F1	95.1	94.8	94.1	94.7	94.2	95.4	93.9	94.5	
52-305CMS × 52-407,F1	91.6	89.3	92.1	91.0					
52-305CMS × 52-307,F1	93.9	93.1	93.9	93.6					
52-430 × 54-520,F1	93.6	91.7	93.4	92.9					
52-305CMS × 54-520,F1	91.9	92.1	92.3	92.1					
52-305CMS × 54-565,F1	94.5	95.2	94.9	94.9					
52-305CMS × 54-458,F1	92.6	90.9	91.9	91.8					
52-305CMS × 54-346, F1	94.7	94.8	95.2	94.9					
52-305CMS × 34,F1	92.8	92.7	93.1	92.9					
54-565 × 52-407,F1	92,8	92.5	92.1	92.5					

[1] Among the 5 common populations, the standard error for dates within each population each year is 0.40.

increase in purity to the last date. This population had the highest purity. All others essentially had attained maximum purity for the first harvest date.

Of particular interest are the percentage sucrose comparisons for populations 52-430 × 54-565,F_1 harvested early, and A56-3 harvested late, approximately one month later. The comparisons are 15.5 and 15.2 for 1961, 16.8 and 17.3 for 1962, and 16.2 and 16.0 for 1963. These data show that there is no difference between the sucrose content of 52-430 × 54-565,F_1 and A56-3 when the former is harvested 1 month earlier than the latter. In 1961, the purities were 95.6 for 52-430 × 54-565,F_1 harvested early, and 92.9 for A56-3 harvested late; in 1962 the corresponding purities were 95.4 and 94.3. In these 2 years, dates of harvest had no appreciable effect on percentage apparent purity. In 1961 the same result was observed for milligrams of total nitrogen per 100 milliliters of thin juice [Payne et al. (2), and Powers and Payne (3)]. Hence the different dates of harvest did not differ materially in regard to percentage apparent purity or concentration of total nitrogen in the thin juice. However, the average root yield of 52-430 × 54-565,F_1 at the earliest harvest date was only 67% of A56-3 harvested a month later. The hybrid equaled A56-3 in percentage sucrose when harvested a month earlier and exceeded it in percentage apparent purity.

In certain years there may be little gain in root weight after September 15, and particularly after October 1. Climatological differences undoubtedly account for these differences. This study indicates that there are no genotypes which reach their maximum weight at an early date in all years. Hence it is likely that any genotype will, on the average, have greater root yield if harvested later. In the case of percentage sucrose, it is clear that populations of sugar beets can be bred, which will have a satisfactory sucrose percentage a month ahead of commercial varieties. However, it is equally clear that if these same populations were grown for another month there would be an increase for the first 2 weeks in all years and a further increase for the next 2 weeks in certain years. Near maximum purity was obtained by September 15 for all populations, except on a high purity hybrid which had a significant increase from the early to the late harvest. Considering all characters it appears that genotypes can be developed in sugar beets, particularly through the use of hybrids, which have acceptable sucrose and purity percentages at an early harvest date. However, these same genotypes will probably show an increase in both root yield and sucrose if grown until the normal harvest date. High quality hybrids can be developed if the economic gain of an extended factory campaign offsets the reduced root yield of an early harvest. The economic relationship between the reduced root yield of an early harvest, and loss by deterioration and rot in storage piles, would also need to be considered.

Summary

Experiments were conducted over 3 years to determine yield and quality responses in sugar beets to 3 harvest dates. Differences between population means for root weight are comparable for each of the harvest dates and each of the years. One harvest date for any of the 3 years would have been sufficient to demonstrate population differences. Certain interactions in sucrose percentage indicate that maximum sucrose in some populations is reached at an earlier date in some years, after which it may even decline. Percentage apparent purity was affected very little by harvest date and year. The interactions, population $\times$ dates, and population $\times$ years, were the only significant sources of interaction variance.

The data indicate the possibility of breeding sugar beet hybrids which will have as high a percentage sucrose, and as high a percentage apparent purity, when harvested a month earlier, as do commercial open pollinated varieties harvested a month later. However, these same hybrid populations, if allowed to grow a month longer (approximating the commercial beet harvest time), will show a corresponding increase in yield of roots and probably percentage sucrose. These increases would probably not be accompanied by an increase in percentage apparent purity. Hence, an early harvest as regards quality is economically feasible.

Early harvest can be used to expedite research where estimates of differences between means of treatments or populations are being determined and where estimates of means are of less concern. High quality hybrids can be developed, if the economic gain from an extended factory campaign would be of greater benefit than the reduced root yield of an early harvest.

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