Sugar Percent in Progenies Derived from Hybrids to Monogerm Sugar Beets

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The monogerm inbred SLC 101 is a necessary component in breeding work for the incorporation of the monogerm character for the immediate future. It is important in breeding work with inbred lines to study combining ability of the line and the pecularities of segregation when the given line is crossed to other varieties. Characteristics of an inbred line, based upon study of F_1 and F_2 hybrids derived from it, can give more important indications of inherent possibilities than the characteristics of the line itself. Such a study of an inbred line may be made when the line is relatively uniform.

Sublines derived from selfing SLC 101 for three generations showed that SLC 101 is relatively uniform for type of flowers, fruits and inflorescences, also for type of roots and foliage. SLC 101 appeared to be homozygous with respect to genes for many morphological characters and for self-fertility. This uniformity indicates that SLC 101 had probably been selfed for at least four to seven generations under open pollination before it was found *in* 1948 (6) .[2]

Because of the genetic uniformity of SLC 101, a study of its F_1 F_2, F_H hybrids and backcross populations makes possible some predictions as to performance in new F_1, F_2 and backcross hybrids. These hybrids are also important for further selection work. Breeding for the monogerm character and for disease resistance is discussed in other papers (3 and 5) .

Material and Methods

All $\mathbf{F_1}$ hybrids with SLC 101 were obtained by pollination of self-sterile multigerm beets with white hypocotyl color rr (4) by pollen from SLC 101. SLC 101 is homozygous RR for red hypocotyl color and when white rr self-sterile plants were used, all F_1 hybrids were heterozygous reds (Rr) . A description of all the varieties used is shown in Table 1. F_2 populations were obtained by self-pollination of F_1 plants under paper bags and by open pollination. F_1 hybrids derived from crosses of the multigerm varieties with SLC 101 were planted in isolations for propagation. In a preliminary test, single rows of four F_2 populations and nine b_1 populations were grown at Granger, Utah, in comparison with the commercial variety US 22/3 (Table 2) . Each row was divided into three equal lengths for harvest data, and an estimated precision of the experiment is shown in Table 2. No injury from curly top was observed.

Sucrose percentage and purity determinations (six samples for each hybrid) were made at the Salt Lake City Station under supervision of C. H. Smith. A portion of the leaded filtrate from each sample was preserved at about 40° F. and from this a sodium determination was made later by Myron Stout and C. H. Smith by use of the Amalgamated Sugar Company's spectrophotometer at Ogden, Utah.

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[2] Numbers in parentheses refer to literature cited.

Table 1.—Description of Varieties.

Variety and S. L. Number	Description
SLC 101	Self-fertile monogerm inbred
US 22/3	Commercial curly-top-resistant variety
US 75	Non-bolting curly-top-resistant variety
US 216	Leaf-spot-resistant high-sugar variety
Klein E	Kleinwanzleben E yield type from Germany—also known in U.S.A. as R. and G. Old Type
Klein ZZ	Kleinwanzleben ZZ, an extreme sugar type from Germany
Lanker	Fodder beet variety from Germany
Ovana	Otoftegaard, half-sugar fodder beet from Denmark
Red table beet	Extra early Egyptian red table beet from W. Atlee Burpee Company
SL 83-3	Refers to selections for large seed balls with elongated inflorescence from SL 941
SL 824	A high sugar curly-top-resistant variety, also known as US 35/2
SL 92	A yield-type variety very high in curly-top-resistance, selected from US 22/3
SL 941	An F_2 from the high-sugar variety US 35 x US 22/3

Experimental Results

Variation in Sugar Percentage in F_2 Populations

SLC 101 when hybridized with a range of multigerm varieties produced very distinct F_2 populations. The F_2 populations derived from hybrids with high-sugar type varieties were high in sucrose percentage (25 percent above US 22/3), but were low in tonnage. The F_2 populations derived from hybrids between SLC 101 and yield-type varieties produced satisfactory sucrose percentage and the yield of gross sugar per acre exceeded that of the commercial sugar beet US 22/3 (Table 2).

Different F_2 populations obtained from open-pollinated F_1 plants showed better tonnage than F_2 populations after selfing, and the average sugar percentage did not decrease with open pollination (Table 3).

Variation in Sugar Percentage in b_1 Populations

Eight of the nine b_1 triple hybrids yielded more sugar per acre than the commercial variety US 22/3 (Table 2). Some striking differences were obtained from different parental combinations. In a preliminary test the triple hybrid SL 824 x (Ovana fodder beet x SLC 101) produced the highest sugar per acre and 45 percent more than the commercial variety US 22/3. The yield of this triple hybrid was 35.4 tons per acre with 15.84 percent sucrose as compared with 29.4 tons per acre and 13.16 percent sucrose for US 22/3. The triple hybrid involving the Early Egyptian red table beet and SL 824 with SLC 101 also produced a very high yield and 33 percent more sugar per acre than US 22/3.

Segregation for Sugar Content in Different Inbred Lines

Inbred monogerm lines obtained from hybrids between different multigerm varieties and SLC 101 may be very valuable as a source for improvement of sugar percentage, since the inbred lines coming from such hybridizations have given a considerable range of sucrose percentages. Two years' results at Salt Lake City showed that inbred lines derived from hybridization of SLC 101 with multigerm varieties differing in sucrose percentage were very distinct. In most cases inbred lines, derived from crosses with SLC 101 and the high-sugar type varieties, developed higher average sugar and percent solids than the lines derived from crosses with low-sugar type varieties (Table 4). The inbred lines derived from sugar-type parentage produced new self-fertile progenies whose refractometer readings were higher by 2 to 5 percent than those for progenies from lines derived from crosses to low-sugar type multigerm varieties. Each self-fertile F_2 beet with high sugar content is a potential high-sugar inbred line.

Discussion

Possibilities of Regulating Sugar Percentage by the Backcross Method

The backcross method (7) facilitates combining the monogerm character with resistance to different diseases such as curly top. At the same time it is possible to change the relation between sugar percentage and yield in the new varieties. The best way to do this is to utilize disease-resistant varieties which are distinct with regard to sugar type and yield type, and F_1 hybridization and for subsequent backcrosses. The results in 1950 and 1951 showed that use of curly-top-resistant varieties which differed in sugar

Table 2.—Variety Test, Granger, Utah, 1951, from Systematic Single Row Planting, with Each Row Divided into Three Lengths.

Variety or b_1 and F2 parentage	Acre Yield Gross sugar lbs.	Percent of US 22/3	Tons beets	Percent sucrose	Percent Na
US 22/3, SL 96	7,738	100	29.4	13.16	0.112
b_1 or 1st Backcross Generation Hybrids					
SL 824 x (Red beet x SLC 101)	10,314	133	35.2	14.65	0.071
SL 824 x (Ovana x SLC 101)	11,215	145	35.4	15.84	0.061
SL 92 x (SL 92 x SLC 101)	8,026	104	31.9	12.58	0.115
SL 92 x (SL 92 x SLC 101)	8,326	108	30.5	13.65	0.115
SL 824 x (SL 92 x SLC 101)	8,474	110	29.1	14.56	0.079
SL 83-3 x (SL 92 x SLC 101)	8,256	107	31.2	13.23	0.126
SL 83-3 x (SL 92 x SLC 101)	8,776	113	30.2	14.53	0.082
US 75 x (SL 92 x SLC 101)	8,020	104	28.3	14.17	0.104
SL 824 x (US 216 x SLC 101)	7,419	96	24.5	15.14	0.080
F_2 Generation Hybrids					
Klein ZZ x SLC 101	7,132	92	21.6	15.31	0.078
SL 92 x SLC 101	8,601	111	27.8	15.47	0.091
SL 92 x SLC 101	6,448	83	20.6	15.65	0.085
Lanker x SLC 101	9,179	119	44.3	10.36	0.154
General MEAN of all varieties	8,423		30.0	14.25	0.095
S. E. of MEAN	688[2]		2.16[1]	0.55[1]	0.010[1]
Sig. Diff. (19:1)	1,947		6.21	1.01	0.028

[1] Standard errors were calculated by considering the three subdivisions of the long 420 ft. single rows as three replications. Therefore, these standard errors give only a rough estimate of the experimental error.
[2] Calculated by short-cut formula.

percentage and yield produced relatively high curly-top resistance and at the same time made it possible to change the sugar percentage and yield in the different backcross populations.

When low sugar backcross combinations of the type SL 92 x (SL 92 x SLC 101) were made the sugar percentage was about the same as that for the commercial variety US 22/3 but the yield of gross sugar was 4 to 8 percent better than US 22/3 (Table 2). Sugar percentage was increased by backcrossing the same F_1 hybrids to the sugar-type variety SL 824. These high sugar combinations did not produce high tonnage but the gross sugar exceeded that of the commercial variety US 22/3 by 4 to 10 percent. F_1 hybrids between SLC 101 and high sugar multigerm varieties backcrossed to high (Table 2). The very high sugar percentage in these triple hybrids (between three high-sugar varieties) produced populations which are very valuable for breeding work when it is desired to increase sugar percentage.

A study of the backcross hybrids obtained from different combinations showed that the most valuable hybrids were obtained when varieties of different types, yield type and sugar type, were alternated in the backcrossing procedure. Diversity in parental combination for tonnage and sucrose percentage can effect increased possibilities in the breeding work that follows. Alteration of parental varieties when the backcross method is applied facilitates breeding work with monogerm beets. Such alteration of parentage increases the percentage of plants which combine desirable sugar content and tonnage in the first hybrid generations and does not diminish the grade of resistance to diseases.

High Yield Combined with High Sugar Percentage in b_1 Hybrids

Two b_1 populations, SL 824 x (red table beet x SLC 101) and SL 824 x (Ovana Fodder beet x SLC 101), produced remarkable yields. The high yields from these two triple hybrids must be due to inherent properties transmitted by the red table beet and by the Ovana fodder beet respectively. The Early Egyptian red table beet imparted a tendency for early root development, a property which is much needed in commercial sugar beet varieties. The same triple hybrid also offers opportunity for incorporation of the monogerm character with a shorter global type root. The Ovana half-sugar fodder beet, of course, imparted a very high yielding tendency. Another interesting feature of both of these triple hybrids was the low sodium percentage, 0.071 and 0.061 percent respectively, as compared with 0.112 percent from US 22/ (Table 2). The high sugar percentage from SL 824 and SLC 101 was undoubtedly responsible for this lower sodium content because of the negative correlation between sugar and sodium percentage **(1)**.

Table 3.—Yield and Sugar Percentage in Fa Hybrids Derived from Open-pollinated and from Selfing F_1 Plants, in June 21 Planting, 1950, at Salt Lake City, Gallinat Field.

Type of pollination in F_1	Number of populations	Average sugar percentage	Average weight per root in lbs.
Selfing	6	16.10	0.74
Open pollination	5	16.4	1.01

F_1 Male-Sterile Hybrids

Hybrids made by utilization of cytoplasmic male sterility make it possible to produce a quantity of certified F_1 or b_1 seed for commercial use. Several such F_1's were produced by use of the monogerm SLC 101 inbred line as the pollen parent. Results with these hybrids are given in another paper by Murphy, Ryser and Owen (2). These results confirm the general results obtained by the F_2 and b_1 populations shown in Table 2 with regard to the relatively high sugar percentage which the inbred SLC 101 imparts to its hybrid offspring.

Table 4.—Percent Solids in Individual Beets in Different F_2 and b_1 Populations Compared with Parental Monogerm Inbred SLC 101[1].

Parental inbred SLC 101 and Hybrid offspring	Year	Frequency distributions on percent solids																	Total beets	Ave. solids	Stand. Deviation	Coef. of variation
		15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31				
																			Number	%	%	
Monogerm SLC 101	1950					1			3	4	3	4	4	1					20	24.0	1.92	8.00
Selfed																						
F_2 (SL 92 x SLC 101)	1950			1		7	12	8	7	11	6	6	2						35	21.8	2.11	9.68
F_2 (SL 92 x SLC 101)	1951	1		3	5	8	16	9	9	9	4	0	1						65	20.7	2.08	10.10
F_2 (Klein E x SLC 101)	1951			1		4	9	7	7	3	3	1							35	21.1	1.73	8.24
F_2 (SL 941 x SLC 101)	1950							2	10	10	6	2							30	23.4	1.29	5.51
F_2 (SL 941 x SLC 101)	1951							2	1	4	6	10	7	3		1	1	2	37	25.2	2.72	9.17
F_2 (Klein ZZ x SLC 101)	1950						1		4	1	3	10	7	7	5	2			40	25.6	2.07	8.09
F_2 (Klein ZZ x SLC 101)	1951							2	8	19	25	16	20	14	2	1			107	24.6	1.60	6.84
Open pollinated																						
F_2 (SL 92 x SLC 101)	1950		1	1	3	8	22	48	50	42	29	9							213	21.9	1.61	7.35
b_1, SL 92 x (SL 92 x SLC 101)	1950				5	8	22	20	24	18	10	1							108	21.4	1.63	7.61
b_1, SL 941 x (SL 92 x SLC 101)	1950						1	8	9	15	2	1							29	22.5	2.01	4.53

[1]The percent solids were lower in 1951 than in 1950 by 4 percent. Therefore, the 1951 frequency distributions were adjusted on this basis; i.e. they were increased or shifted to the right by 4 percent.

Summary and Conclusions

Hybridization of the monogerm inbred line SLC 101 with different multigerm varieties of beets showed that SLC 101 may be described as an inbred line which improves sugar percentage in hybrid combinations. The backcross method facilitates combining the monogerm character with resistance to different diseases. At the same time it makes possible the production of hybrid populations with a desirable combination of sugar and yield for breeding work. Xhe easiest way to obtain such populations consists in making subsequent backcrosses to varieties distinct in sugar and tonnage, which are, at the same time, resistant to the given disease.

Very promising results were shown in triple hybrid combinations. The triple hybrid which produced the highest yield of sugar per acre included parentage from the high-sugar variety US 35/2 and the Ovana half-sugar fodder beet with the inbred SLC 101.

Literature Cited

(1) DOXTATOR, C. W. and CALTON, F. R.
1950. Sodium and potassium content of sugar beet varieties in some western seed growing areas. Proc. Amer. Soc. Sugar Beet Tech.: pp. 144-151.

(2) MURPHY, ALBERT M., RYSER, GEORGE K. and OWEN, F. V.
1952. Performance of F_1 hybrids between curly-top resistant and susceptible sugar beets. Proc. Amer. Soc. Sugar Beet Tech. pp. 390-392.

(3) MURPHY, ALBERT M. and SAVITSKY, V. F.
1952. Breeding for resistance to curly top in hybrids with monogerm beets. Proc. Amer. Soc. Sugar Beet Tech. pp. 387-389.

(4) OWEN, F. V. and RYSER, GEORGE K.
1945. Some Mendelian characters in *Beta vulgaris* linkages observed in the Y-R-B Group. Jour. Agric. Res. 65 (No. 3) : pp. 115-171.

(5) SAVITSKY, V. F.
1952. Methods of results of breeding work with monogerm beets. Proc. Amer. Soc. Sugar Beet Tech. pp. 344-350.

(6) ————
1950. Monogerm sugar beets in the United States. Proc. Amer. Soc. Sugar Beet Tech.: pp. 156-159.

(7) ————
1934. Backcross method in sugar beet breeding (In Russian) . Scientific notes of the Institute of Sugar Industry: Vol. 40 (2) : pp. 1-17.