Increased Yield and Purity of Hybrids from the Ovana Fodder Beet

MYRON STOUT, GEORGE K. RYSER, ALBERT M. MURPHY AND F. V. OWEN[1]

Received for publication June 19, 1961

Introduction

High yield of sugar per acre combined with high purity and a high degree of disease resistance is the ultimate goal of sugar beet breeders, farmers, and processors. These three factors may be equally important to the economy of a healthy industry, but usually a compromise is made in choosing the best variety to grow in a given area. Under epidemic disease conditions, disease resistance may be the controlling factor in obtaining high yields. In this case quality is most likely to suffer. Recent increases in the use of nitrogen fertilizers have also favored high yields of lower quality beets. For a long time sugar beets have been referred to as "yield types" or "sugar types" because these two characters do not usually occur together. However, recent progress in hybrid breeding has shown that these characters are not entirely incompatible. Controlled hybridization by use of genetic male sterility (4, 5)[2] offers many new possibilities for synthesizing desirable combinations of characters. A second-generation backcross from the Ovana fodder beet to sugar beets, designated SL 630, may be considered an example of such possibilities.

Normally the roots of sugar beets do not increase in size very rapidly until they develop a fairly large canopy of leaves. However, a rather wide heritable variation exists with regard to the time required to reach this stage of rapid root growth. Savitsky (9) has shown that yield types reached this development stage earlier than sugar types and that fodder beets reached this stage much earlier than either type of sugar beets. From June until September fodder-beet roots were more than twice the size of sugar beet roots. Obviously any decrease in the time required from planting to the stage of rapid root growth should be equivalent to an extension of the growing season and should increase yields accordingly. If heterosis depends upon synergy between dissimilar genes, hybrids between fodder beets and sugar beets might be expected to produce some valuable new material from which selections can be made for desirable characters.

[1] Physiologist, Research Agronomists and Geneticist, respectively, Agricultural Research Service, Crops Research Branch, U. S. Department of Agriculture.

[2] Numbers in parentheses refer to literature cited.

Breeding Materials and Methods

Included in the parentage of the hybrid SL 630 was the Ovana fodder beet, the sugar type variety US 35, and the high-sugar high-purity inbred CT8. Seed of the Ovana fodder beet was obtained from Dr. K. J. Frandsen of the Otoftegaard Breeding Station, Taastrup, Denmark. In common with other vigorous-growing fodder beet varieties the Ovana has a prodigious growth potential but is low in sugar and purity. It is also highly susceptible to curly top. Unlike roots of many other European fodder beet varieties the Ovana roots are not highly colored with red or orange pigment. They are white like sugar beets but are characterized by green color on the upper part of the roots exposed to sunlight because of their protrusion above the soil surface.

Roots of the Ovana fodder beet variety have certain characteristics similar and dissimilar to those of sugar beets. They are similar to sugar beets in amino nitrogen, very much lower in respiration rate, much higher in sodium content, and slightly higher in potassium. However, the potassium content of Ovana roots is much lower than one might expect in sugar beets with a very low sugar and high sodium content.

US 35 is a sugar-type, curly-top-resistant variety developed by selection from US 22/3. After the discovery of Mendelian male sterility in US 35 a backcross population was developed in which 50 percent of the plants were *aa* recessive with aborted pollen. Mendelian male-sterile *aa* segregates from this backcross population were hybridized with Ovana pollinators for the production of the F_1 generation hybrid. The F_1 hybrid was used to pollinate other male-sterile US 35 plants for production of the b_1 generation hybrid (See Figure 1).

The inbred CT8 (6, 8) was derived from a single self-fertile beet selected in 1952. It is a high-sugar type, high-purity inbred moderately low in amino nitrogen, sodium, potassium, and respiration rate. Previous field tests with hybrids of CT8 have indicated only average to poor combining ability. Beets of the inbred CT8 were relatively high in curly-top resistance, but at Jerome, Idaho, they were readily dwarfed by the disease without showing typical leaf symptoms. Mendelian male sterility was observed in selfed progeny of the original CT8. This inbred can, therefore, be used as a male or female parent in hybrid combinations.

A single beet from the b_1 population US 35 $\times$ (US 35 $\times$ Ovana) was used as the female in producing the hybrid SL 630. Details of the selection were as follows: From a field planting

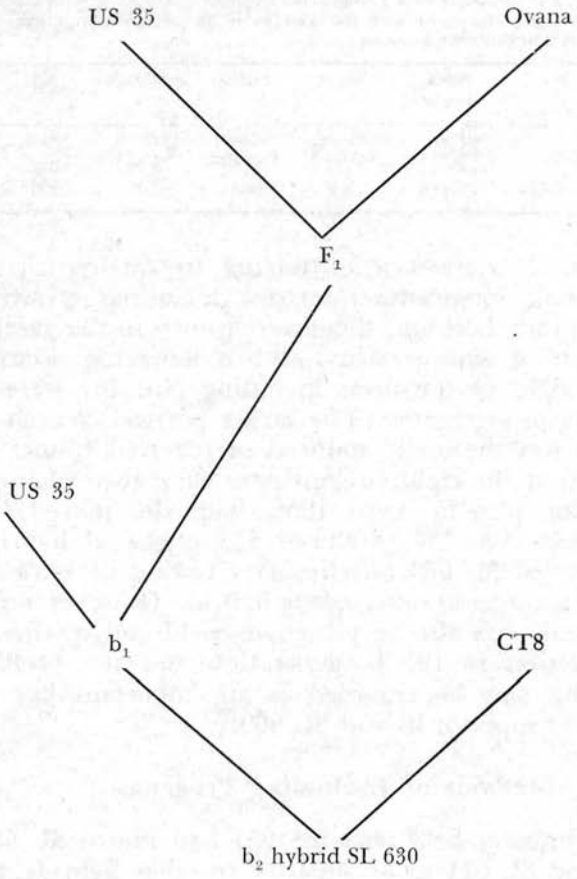

Figure 1.—Parentage of the b_2 generation hybrid sugar beet SL 630. The b_1 parentage consisted of one highly selected beet. (See Table 1)

of approximately 2,000 beets of the b_1 population, 158 individuals were selected for desirable root type. Some of the larger individuals resembling fodder beets as well as smaller ones more typical of the sugar beet parent were rejected. A preliminary test for dry substance was made with the Abbe refractometer (10) and the 15 highest were chosen for more complete chemical analysis. Sugar, total soluble solids, amino nitrogen, sodium, and potassium were determined. The highly superior beet No. 487 became the female parent of hybrid SL 630. The outstanding qualities of beet No. 487 in comparison with the average of the selected group of 15 from which it was chosen is shown in Table 1. Beet No. 487 was not only much larger but was superior in

Table 1.—Record of parental beet number 487 selected from the b_1 generation [US 35 × (US 35 aa × Ovana)] compared with the average of 15 selected sister beets from the same population grown at the same location.

Beet number	Root weight	Sugar	Purity	Amino N	Na	K
	grams	percent	percent	percent	ppm	ppm
487	2500	17.6	91.9	0.24	280	2210
Average of 15 selected beets	1771	17.0	88.4	0.46	290	3280

all the chemical characteristics related to quality that were measured. Small longitudinal sectors, including crown buds, were cut from each beet and these were grown in the greenhouse for observation of male sterility. When flowering occurred in March 1956, eight of the beets including No. 487 were found to be male-sterile segregates. The larger portion of each of the selected beets was thermally induced in the cold frame. These larger portions of the eight *aa* segregates were then planted in a garden isolation plot in April 1956, with the inbred CT8 as pollinator. Beet No. 487 produced 532 grams of hybrid seed which was labeled SL 630. Preliminary testing in 1957 showed that SL 630 was the most outstanding hybrid. However, one sister progeny, SL 631, was also very high in yield and quality. This fortunate selection in the b_1 generation and the preliminary progeny testing may be regarded as an important key to the discovery of the superior hybrid SL 630.

Methods of Evaluating Progenies

After preliminary field tests in 1957 had shown SL 630 and its sister hybrid SL 631 to be superior to other hybrids, SL 630 was extensively tested at Jerome, Idaho, and at Salt Lake City, Utah, in 1958. All parental lines and hybrids except the inbred CT8 were included in the test. The inbred CT8 was not included in the replicated test because of its poor vigor but it was included in adjacent unreplicated plots for general observation. The five varieties were replicated in randomized blocks. The data at Salt Lake City were based on twenty replications of 2-row plots 22 feet long; at Jerome, Idaho, eight replications of 2-row plots 50 feet long. The rows were 20 inches apart at Salt Lake City and 22 inches apart at Jerome, Idaho. The Jerome plots were planted on soil classified as Portneuf silt loam, deep phase, good drainage (1). The soil was low in salinity and high in fertility but not excessive in nitrogen. The plots at Salt Lake City were planted on Welby fine sandy loam (3) which was very high in salinity and fertility. Two spacings, 10 inches versus 15 inches between beets, were compared. An extra amount of

nitrate was added to half these plots. The varieties were randomized within each spacing and the spacings were alternated systematically within fertility levels. The extra-high fertility made practically no difference in yield or chemical analysis, and 15-inch spacing gave the same yield as the closer spacing with only a small reduction in quality; so the data for spacings and fertility levels were combined in Table 2. Spacings within the rows at Jerome was uniform. The beets were spaced approximately 12 inches apart.

Two 10-beet samples per plot were taken for sugar and other chemical analyses at both Jerome and Salt Lake City. Pulp samples from the Jerome plots were frozen and all chemical analyses were made at Salt Lake City. In addition to the usual sugar and apparent purity determinations, analyses were made for amino notrogen, sodium, and potassium by methods previously described (11). Amino nitrogen as glutamine reported here is based on the molecular weight of glutamine rather than its amino nitrogen content. Since glutamine contains only 9.59 percent amino nitrogen the true amino nitrogen values are only 9.59 percent of those reported.

Experimental Results

Curly top was moderately severe at Jerome, Idaho, in 1958. This degree of infection was expected because the experimental plot adjoined the desert breeding area of the beet leafhopper (*Cerculifer tenellus*). On August 1, 94 percent of the Ovana fodder beets were obviously affected by the disease. In contrast only 15 percent of the F_1 hybrids (US 35 $\times$ Ovana) and still smaller percentages of the other varieties were obviously affected. By harvest time all the Ovana fodder beets were severely injured but since the infection came late in the season most of the beets survived and a yield of 13.1 tons per acre was produced.

Curly-top exposure at Salt Lake City was rather severe but even later in the season than at Jerome. At harvest all Ovana fodder beets were injured so that they yielded only 15.9 tons per acre. At Salt Lake City some F_1 hybrids showed mild curly-top symptoms before harvest in 1958 but apparently yielded nearly normally.

Yield and sugar percentage

At Jerome, Idaho, all the F_1, b_1, and b_2 hybrids produced yields in excess of 30 tons per acre (Table 2). The yield of 27.3 tons per acre and 18.7 percent sugar by US 35 is considered an excellent yield. US 35 produced 9,995 pounds of sugar per acre. However, SL 630, with a yield oof 33.2 tons and 18.3 percent sugar, yielded 11,865 pounds of sugar per acre. The low yield

Table 2.—Second-generation hybrid SL 630 compared with the F_1 and b_1 hybrids and with parental varieties US 35 and the Ovana fodder beet at Jerome, Idaho, and Salt Lake City, Utah, 1958.

Current S.L. number	Description	Acre Yield		Sucrose	Purity	Amino N	Na	K	Curly-top August 1	Beets per 100-feet of row
		Sugar	Tons							
		Pounds	Beets	Percent	Percent	Percent	ppm	meq/100	Percent	
		Jerome, Idaho—8 replications each								
308	Ovana	8,305	18.1	18.1	89.8	.33	54	222	94.1	86
308+5	F_1 (US 35 × Ovana)	9,915	32.1	15.9	92.0	.34	29	248	14.8	98
431+5	b_1 [US 35 × (US 35 × Ovana)]	10,510	31.4	17.1	92.6	.31	23	228	9.9	105
024	US 35	9,995	27.3	18.7	92.3	.32	16	194	7.9	100
630	(b_1 × CT8)	11,865	33.2	18.3	94.1	.34	19	174	3.5	96
	LSD 5%	1,040	3.19	0.54	0.97	NS	5	34		
		Salt Lake City, Utah—20 replications each								
308	Ovana	2,939	15.9	8.4	70.6	.92	267	294	Severe[1]	71
308+5	F_1 (US 35 × Ovana)	9,282	41.7	11.1	79.4	.83	129	399		109
431+5	b_1 [US 35 × (US 35 × Ovana)]	9,652	38.3	12.7	81.2	.90	100	407		108
024	US 35	9,468	32.8	14.4	83.8	.82	86	415		104
630	(b_1 × CT8)	12,084	40.9	14.8	85.4	.69	73	372		105
	LSD 5%	856	3.59	0.56	1.60	.08	18	18		

[1] At Salt Lake City nearly all Ovana plants were badly injured by curly top. In the F_1 hybrids very mild symptoms were evident on most plants, but this degree of infection did not appear to interfere with growth. Mild curly-top symptoms were evident on only occasional plants of the other three more highly resistant varieties.

of 13.1 tons per acre and abnormally high sugar percentage of the Ovana fodder beets may be explained by the effect of curly top. At harvest most of the leaves were dead and the roots were somewhat desiccated.

Yields were all higher and sugar percentages were lower at Salt Lake City than at Jerome, Idaho. Hybrid SL 630, in spite of its extremely high yield, had a sugar percentage of 14.8 percent compared with 14.4 percent for variety US 35. The difference of 0.4 percent sugar is not statistically significant but the fact that the high-yielding beets of hybrid SL 630 were equal to that of the sugar type variety US 35 was surprising and rather remarkable. The sugar per acre yield for SL 630 was 12,084 pounds in comparison with 9,468 pounds for US 35. This difference is highly significant and amounts to an increase of 28 percent over that of US 35.

In 1959 unreplicated plots of SL 630, SL 631, and Ovana were planted at Salt Lake City. The data obtained confirmed earlier replicated tests. SL 630 indicated a yield of 12,760 pounds of sugar per acre in comparison with 11,184 pounds for SL 631. Curly-top exposure was very light in 1959. Under these conditions and lacking competition the Ovana variety yielded 78 tons per acre with 5.7 percent sugar for a gross sugar yield of 8,960 pounds per acre.

Purity and components of purity

The hybrid SL 630 was significantly superior in purity to the sugar-type variety US 35 at both locations under widely different conditions of salinity and nitrogen fertility. This high purity of hybrid SL 630 may be partly explained by considering some of the individual components of impurity (6). Differences in the three individual components of impurity were not statistically significant at Jerome, but at Salt Lake City under both high salinity and nitrate fertility which depressed both sugar percentage and quality of all varieties SL 630 was quite superior. Both amino nitrogen and potassium content were significantly lower in SL 630 than in US 35. Although the difference in sodium content was not significant it favored SL 630 over US 35.

Discussion

Unless one considers the components of impurity individually, it would seem incredible that the low-purity Ovana variety should have contributed anything toward improved purity in its hybrid offspring. Undoubtedly a very significant factor was the highly superior beet selected in the b_1 parental line (Table 1). Since CT8 hybrids have not been particularly outstanding in previous hybrid combinations, the superiority of SL 630 might be con-

sidered a rather specific case of genetic heterosis for quality factors as well as for yield.

Previous studies of fodder beets and half-sugar beets have shown them to be low in respiration rate (10). The respiration-rate studied on individual beets in 1959 confirmed this general observation for the Ovana variety. The Ovana fodder beet was extremely low in respiration rate. This fact might be explained on the basis of its very low sugar percentage, but three one-eighth-Ovana hybrids, including SL 630 and SL 631, were also low in respiration in comparison with the sugar beet variety with which they were compared. There is little doubt that the low respiration rates of the Ovana hybrids were inherited from the Ovana rather than due to low sugar percentage. Respiration rates between 70 and 90 mg of CO_2 per kg per hour are usual for sugar beets (10). In the 1959 tests the rates for US 41, Ovana, and the three one-eighth-Ovana hybrids were 70, 50, and 60 to 62 mg CO_2 per kg per hour, respectively.

Development of the hybrid SL 630 may therefore be considered an approach to the breeding of superior-quality and high-yielding sugar beets. Valuable information may be lost by considering purity determinations alone without information on some of the respective components of purity. Furthermore, the determinations for amino N, Na, and K may be more accurate than purity determinations because errors in sugar as well as dry-substance determinations are involved in the purity values. The ease and rapidity of the amino N, Na, and K determinations, and the fact that they may be made with less than 20 ml of the same clarified filtrate used for sugar analysis, make the separate determinations especially well adapted for breeding and selection work (10). If the trend toward excessive use of nitrogen fertiliers ccontinues (2, 11), selection work for low amino N and other constituents of impurity in the beet root should warrant extensive investigation because it has been shown (11) that a high uptake of nitrate increases the uptake of Na and K and thus decreases the purity of the sugar beet and increases the difficulties of sugar extraction (7).

Summary

A high-yielding curly-top-resistant sugar beet hybrid with relatively high sugar percentage and exceptionally high purity was developed by utilizing the Ovana fodder beet in the parentage. The selection of a highly superior beet made in the b_1 generation hybrid US 35 × (US 35 × Ovana) for high root weight, high sugar percentage, low amino nitrogen, low Na, and low K was undoubtedly responsible for the superior performance of

SL 630. These selected b_1 beets were then crossed to the inbred CT8. All crossing was effected by the use of mendelian male sterility. The final selected hybrid was higher in curly-top resistance than either of the two curly-top-resistant parents US 35 or CT8. This high degree of curly-top resistance and the remarkable yield and low respiration rate may be largely attributed to hybrid vigor and high yield prepotency derived from the Ovana fodder beet. The Ovana fodder beets were very high in yield and sodium content. They were very low in sugar and respiration rate. The selection in the b_1 generation and hybridization to the high-sugar, high-purity inbred CT8 produced a hybrid that combined the good qualities of all three parents.

Literature Cited

(1) BALDWIN, MARK and YOUNGS, F. O. 1925. Soil survey of the Twin Falls Area, Idaho. Field operations of the Bureau of Soils, 1921, pp. 1367-1394, U. S. Department of Agriculture.

(2) HADDOCK, JAY, et al. 1959. The influence of cultural practices on the quality of sugar beets. J. Am. Soc. Sugar Beet Technol. 10 (4) : 290-301.

(3) JENNINGS, D. S., et al. 1946. Soil survey, Salt Lake area, Utah. Series 1936, No. 22, 83 pp. U. S. Department of Agriculture.

(4) OWEN, F. V. 1952. Mendelian male sterility in sugar beets. Proc. Am. Soc. Sugar Beet Technol. 7:371-376.

(5) OWEN, F. V. 1954. Hybrid sugar beets made by utilizing both cytoplasmic and Mendelian male sterility. Proc. Am. Soc. Sugar Beet Technol. 8 (part 2) : 64.

(6) OWEN, F. V., et al. 1960. Interaction of components of impurity and location in hybrids from inbred lines of sugar beets. J. Am. Soc. Sugar Beet Technol. 11 (1) : 37-43.

(7) ROUNDS, HUGH G., et al. 1958. A study and economic appraisal of the effect of nitrogen fertilization and selected varieties on the production and processing of sugar beets. J. Am. Soc. Sugar Beet Technol. 10 (2) : 97-116.

(8) RYSER, GEORGE K., et al. 1959. Some chemical and physiological characteristics of inbred lines of sugar beets. J. Am. Soc. Sugar Beet Technol. 10 (6) : 525-543.

(9) SAVITSKY, V. F. 1950. A method of selection for earliness of root development in sugar beets. Proc. Am. Soc. Sugar Beet Technol. 6: 195-197.

(10) STOUT, MYRON. 1954. Determining respiration rate and sampling for chemical analysis of sugar beets. J. Agr. and Food Chem. 2 (26) : 1324-1328.

(11) STOUT, MYRON. 1961. A new look at some nitrogen relationships affecting the quality of sugar beets. J. Am. Soc. Sugar Beet Technol. 11 (5) : 388-398.