Progress in the Development of Soil - Free Sugarbeets*

Gerald E. Coe and Clair Theurer

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INTRODUCTION

Present-day sugarbeet varieties have indented root sutures packed with small fibrous roots. Soil clings to these rootlets as the beets are lifted from the ground by harvesters. Mechanical cleaning equipment on harvesters and piling machines damage the roots while removing the adhering soil. Damaged beets respire more rapidly than unblemished beets, resulting in an excessive loss of sugar. The concept of a clean smooth sugarbeet taproot is not new. H. L. Kohls (2) worked toward this goal in the 1950's. G. W. Deming began work on sugarbeet X garden beet crosses in the 1930's. In 1950, (1) he reported gross sugar yields not significantly different from the local Colorado commercial variety, but with 1 to 2 percentage points lower sugar content. During World War II when labor was scarce and before the advent of sugarbeet harvesters there was considerable interest in Deming's globe-shaped "sugarbeets" because they could be harvested with a potato digger. Work was discontinued with this breeding material primarily because successful harvesters were introduced. In 1968, a soil-free breeding program was initiated at Beltsville because of renewed interest in reducing storage pile losses. This paper reviews current progress in development of soil-free sugarbeet.

MATERIALS AND METHOD

The original plant material used in the breeding

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*Contribution for the U.S. Department of Agriculture, Agricultural Research Service. The authors are Research Geneticist, Plant Genetics & Germplasm Institute, Germplasm Quality and Enhancement Laboratory, Beltsville, MD 20705 and Crops and Research Geneticist, Entomology Research, Agricultural Research Service, U.S. Department of Agriculture, East Lansing, MI 48823, respectively.

program consisted of beets of the Deming lines which were all white and globe-shaped, but because of their susceptibility to Cercospora leaf spot at Beltsville and perhaps also to Aphanomyces black root the taproots were quite small (4 or 5 tons per acre) and low in percent sucrose (some as low as 3%). Plants selected from Deming's lines were crossed with open-pollinated multigerm sugarbeet selections considered to have good resistance to leaf spot and black root. In subsequent generations, selections were made for root type and leaf spot resistance, and the selected lines were analyzed for sucrose concentration. After two or three cycles of mass selection for yield, sucrose content and leaf spot resistance, they were again crossed to our best open-pollinated multigerm black root and leaf spot resistant breeding lines and the cycles of selection repeated. There has been a total of 4 crosses to these resistant breeding lines.

Selections were made for taproots without an indented suture, with a reduced number of rootlets scattered over a large percentage of the root surface and for non-sprangled roots. It was recognized very soon in the breeding program that the taproot needn't necessarily be globe-shaped and sit high in the ground to be relatively free from soil. The taproot features causing soil to adhere are: (1) sprangling of the root, and (2) deeply indented root sutures from which emanate many rootlets.

In 1984, two nursery tests were conducted on two different groups of "soil-free" breeding lines. The nursery test as Beltsville, Maryland was composed of 33 "soil-free" progenies produced in 1983. The three check varieties in this test were USH20, USH23 and Mono-Hy E4. The second nursery test was conducted at the Bean and Beet Experimental Farm southwest of Saginaw, Michigan and was composed of 25 of the most promising "soil-free" progenies tested in 1982 and 1983 at Beltsville, Maryland. These 25 progenies varied in freedom from adhering soil in the Beltsville test. Three smooth root inbred lines from Utah (fodderbeet X sugarbeet selections) and 2 check varieties, USH23 and Mono-Hy E4, were included in the Michigan test. The Utah lines were included because they have well shaped roots without sutures and because they were known to have relatively small amounts of soil adhering to the roots when harvested.

The Beltsville test consisted of 3 replications of single row plots 6.1 meters long in a triple lattice design. The rows were 61 cm. apart and the seeds were planted 15 cm. apart. The Michigan test consisted of 6 replications of two row plots 7.3 meter long in a randomized block. The rows were 71 cm. apart, and plants were thinned to 20 to 30 cm. Three of the replications were harvested by hand, and three were harvested by machine. Hand harvest consisted of lifting the taproot with a beet fork and giving it a gentle shake.

RESULTS AND DISCUSSION

After crossing plants with "soil-free" roots to plants with the ordinary type sugarbeet taproot, the F_1 generation more closely resembled the ordinary type taproot than the "soil-free" type. Only a small proportion of "soil-free" type roots were found in the F_2 & F_3 generations. Crosses between two "soil-free" plants can produce progeny with varying proportions of intergrades between soil-free and ordinary type roots. Our work has not indicated major recessive genes conditioning the soil-free phenotype, but rather that many additive genetic factors are involved. The production of a breeding line with all roots of the desired type has not yet been accomplished.

Root yields improved rapidly during the first two crosses to black root-leaf spot resistant sugarbeets followed by a few cycles of selection. Leaf spot resistance improved rapidly also. Sugar percent increased only slightly and purities were essentially equal to extant hybrids because of their low concentration of nonsucrose solubles (NSS).

Data are presented (Table 1) for 6 progenies considered to be the better ones in the Beltsville test because of good root yield, low content of NSS, good leaf

Table 1. Harvest data of "soil-free" multigerm sugarbeet lines in the 1984 Beltsville late-planted nursery.

Seed No.	Gross Sugar	Root Yield	Sucrose	Nonsucrose Solubles	1/ RJAP	Leaf Spot Rating
	kg/ha 2/	mt/ha	%	%	%	
Mono Hy E4	5715 ABC	39.94 A-F	15.47 A	3.16 A	83.01 A	4.00 BCD
USH20	4501 A-F	31.41 B-F	14.33 BC	2.73 ABC	83.99 A	5.33 A
USH23	3878 DEF	27.96 F	13.87 BCDE	3.13 AB	81.56 A	5.00 AB
SP8450-33	4475 A-F	30.65 C-F	14.60 AB	2.44 ABC	85.63 A	3.67 CD
SP8450-23	4806 A-F	33.54 B-F	14.33 BC	2.64 ABC	84.43 A	3.00 D
SP8450-50	4770 A-F	33.29 B-F	14.33 BC	2.35 C	85.87 A	3.33 CD
SP8450-29	5225 A-E	36.72 A-F	14.23 BCD	2.49 ABC	85.16 A	4.33 ABC
SP8450-41	5854 AB	41.43 ABC	14.13 BCDE	2.48 ABC	85.04 A	3.67 CD
SP8450-9	6103 A	45.65 A	13.37 BCDE	2.30 C	85.28 A	3.67 CD
Other 27 Progenies	4635	34.28	13.52	2.42	84.81	3.64
Means	4736	34.52	13.72	2.48	84.72	3.73
C.V.	17.1	17.2	4.8	15.4	2.8	15.1

1/Raw Juice Apparent Purity

2/Means with same letters are not significantly different at .005.--Duncan's Multiple Range Test

spot resistance or because of a combination of these characteristics. With regard to significant differences between the check varieties and the tested lines, none of the 33 test progenies had significantly less root weight than the check variety Mono-Hy E4; 3 were lower in gross sugar; 32 were lower in percent sucrose; 15 were lower (better), and none were higher (worse) in percent NSS; none were lower in raw juice apparent purity; and none were different in leaf spot resistance. All 33 were significantly better than USH20 in leaf spot resistance and 23 were better than USH23. It is concluded that except for lower sucrose content, the "soil-free" lines are approaching the check varieties' performance at Beltsville.

Similar results were obtained for the 25 progenies tested in Michigan. The soil at harvest time at the Michigan B & B farm was rather dry and was readily removed by the harvester even though the beets were not passed across grab rolls. In the hand harvest, 6 of the progenies yielded as much recoverable sugar as USH23 (Table 2) with one progeny yielding significantly more sugar than USH23 or Mono-Hy E4. All 25 were lower in percent sucrose than Mono-Hy E4, four were appreciably lower in clear juice purity, and ten were lower in recoverable white sugar per acre. The "soil-free" lines compare more favorably with USH23, since USH23 didn't perform as well as Mono-Hy E4.

Table 2. Harvest data of hand-harvested soil-free sugarbeet progenies at the Michigan B & B Experiment Farm in 1984.

Seed Number	Recoverable White Sugar		Root Yield	Sucrose	Clear Juice Purity
	kg/ha	kg/mt	mt/ha	%	%
Mono Hy E4	7306	153.0	47.75	17.8	95.39
USH23	7011	141.5	49.55	16.8	94.40
SP8250-150	8468	131.6	64.35	15.4	95.21
SP8250-144	7540	134.0	56.27	15.9	94.57
SP8250-126	7377	134.3	54.93	16.0	94.40
SP8350-37	7385	135.0	54.70	16.0	94.56
SP8350-99	7115	119.3	59.64	14.5	93.62
SP8250-139	7023	136.8	51.34	16.0	95.16
Av. of other 19 Beltsville Progenies	6397	129.7	49.32	15.4	94.42
Av. of 3 Utah Smooth Root Lines	3894	122.3	31.84	15.1	92.49
Mean	6417	130.5	49.10	15.6	94.26
LSD .05	779	7.8	9.30	.63	1.54
C.V.	10.5	3.5	11.6	2.5	1.0

The results of the machine harvest are presented in Table 3. These results lead to the same conclusions as those of the hand-harvested test. As a group the "soil-free" lines were somewhat lower in sucrose concentration than the hybrid check varieties. In spite of this, the clear juice purities of the "soil-free" lines were almost as high as the two hybrid check varieties. Considering the fact that open-pollinated "soil-free" lines were compared to adapted commercial hybrids, they did rather well

Table 3. Harvest data of machine-harvested sugarbeet lines at the Michigan B & B farm in 1984.

Seed Number	Recoverable White Sugar		Root Yield	Sucrose	Clear Juice Purity
	kg/ha	kg/mt	mt/ha	%	%
Mono Hy E4	6498	144.2	45.06	16.8	95.34
USH23	6192	137.2	45.13	16.1	95.01
SP8250-150	6431	130.2	49.39	15.4	94.77
SP8250-144	6660	129.9	51.27	15.3	95.02
SP8250-126	5987	132.4	45.22	15.6	94.94
SP8350-37	7027	135.5	51.86	15.8	95.32
SP8350-99	6304	119.5	52.75	14.5	93.45
SP8250-139	5988	132.0	45.36	15.7	94.46
Av. of other 19 Beltsville Progenies	5839	128.3	45.51	15.2	94.72
Av. of 3 Utah Smooth Root Lines	3723	118.8	31.34	14.8	92.13
Mean	5784	128.5	44.84	15.3	94.48
LSD .05	1437	7.8	10.76	.76	1.03
C.V.	15.5	3.7	14.7	3.1	.7

except for their sucrose concentration. Recognizing the effect of the inverse relationship of root yield and sucrose percentage, some of the breeding lines were actually reasonably good in sucrose concentration.

The amount of soil remaining on the roots is presented in Table 4. It should first be noted that the coefficients of variation are extremely high. The factors contributing to this are probably root size, variation in soil characteristic from plot to plot, and, in the machine harvest, randomness as the roots passed through the harvester. Nevertheless, there appears to be a trend in favor of the "soil-free" lines. The aberrance of the 3 Utah smooth root lines in the machine harvest is probably due to their small size, the amount of soil remaining on them having to be multiplied by such a large factor to obtain the number of kilograms per ton. Perhaps the slightly different root shape also prevented the harvester

Table 4. Soil remaining on the roots at the Michigan B & B farm in 1984.

	kg. Soil/mt Roots			
	Hand-harvest		Machine-harvest	
Variety	Average	Range	Average	Range
MonoHy E4	92	---	8	---
USH23	77	---	7	---
6 Highest Yielding "Soil-free" Progenies	55	36-71	6	3-8
19 Remaining "Soil-free" Beltsville Lines	60	32-100 1/	8	5-11
3 Utah Smooth Root Lines	34	27-45	13	9-16
LSD .05	46		NS	
C.V.	34.7		61.0	

1/Of these 19 lines 2 had more than 92 kg adhering soil and 5 had between 77 and 92 kg.

from removing the soil as effectively. There was about 10 times as much soil on the hand-harvested roots as on the machine-harvested roots. This suggests that considerable improvement is needed before harvester soil-cleaning equipment can be eliminated. There were great differences among the "soil-free" progenies in the amount of soil clinging to the roots in the hand harvest. The average "soil-free" line had numerically but not significantly fewer pounds of soil clinging to the root in the hand harvest than the commercial check varieties. They undoubtedly could be cleaned with gentler mechanical equipment than is found on existing harvesters. Not so obvious was the tremendous variation within each progeny. Some roots had almost no adhering soil in the hand harvest. If all were as good as the best roots, there would be no need for cleaning equipment on harvesters.

The "soil-free" breeding lines being developed are similar in shape to current commercial cultivars but are somewhat shorter than most. While root yield, quality and resistance to leaf spot and black root are good, these lines must be improved in sucrose content before they will be useful as components of commercial hybrids. The gain in sugar percentage by the soil-free lines has been about ½ percentage point since the third cross to sugarbeets. However, in the time since USH20 was developed new commerical hybrids have increased more than ½ percentage point. Hence, soil-free sugarbeets are now further behind in sucrose percentage when compared to current commercial cultivars.

SUMMARY

Good progress has been made since 1968 in the development of a "soil-free" smooth root sugarbeet. The best lines have little adhering soil, but they are still segregating for root morphology. They are approaching the performance of extant commercial hybrids in root yield, purity and leaf spot resistance, but are about 1 percentage point lower in sucrose content.

LITERATURE CITED

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