Field Evaluation of SR87 Smooth Root Sugarbeet Hybrids

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ABSTRACT

Four smooth root type (SR) experimental hybrid sugarbeets *(Beta vulgaris* L.) were compared in replicated field trials (1988,1989) with standard root type commercial hybrids and smooth root inbred lines for root and sugar yield, clear juice purity, root smoothness score, and pounds of soil harvested per ton of beets. SR hybrids had root yield and clear juice purity readings about equal to the commercial hybrids, but they were significantly lower in recoverable sugar per ton (29 lbs.) and sucrose percentage (l.7%). Two smooth root inbred lines (85700 and SR87) had significantly the best root smoothness scores and the lowest quantity of soil per ton of roots harvested of the 10 entries evaluated. Soil harvested with SR inbreds was 26% less than for SR hybrids, while the commercial cultivars averaged about 36% more soil harvested with the beets than for the SR hybrids. Results demonstrated that SR hybrids with high yield, good quality, and greatly reduced soil tare can be produced. However, a 1% to 2% increase in sucrose percentage must be attained in current SR lines to make SR commercial varieties a reality.

Additional Key Words: *Beta vulgaris* L.; root shape; plant architecture; sugarbeet breeding; harvesting; root storage; processing efficiency; soil tare.

Smooth root (SR) sugarbeet *(Beta vulgaris* L.) hybrids have the potential of great benefit to the sugarbeet industry. Growers would benefit from roots that are easily lifted from the ground at harvest with less wear and tear on equipment, and at least a 50% reduction in the quantity of soil transported to and from receiving stations. Cleaner beets, with less root bruising and breakage and less trash in storage piles, would reduce the loss of sugar that occurs primarily by respiration and overheating prior to processing. SR beets would require less energy and time in the factory to wash and clean prior to slicing. The possibility exists that efficiency of factory processing could be increased by peeling the epidermal layers from the beet root eliminating a significant portion of the impurities that limit recovery of sugar. Narum and Martin (1989) and Edwards et al. (1989) found greater quantities of impurities in the peel than in the rest of the beet root. A SR beet would peel more rapidly than conventional root types and less tissue would be removed in the process. A pilot plant study of high pressure steam peeling of sugarbeets resulted in significantly lower impurities, and higher quality of sugar product, from peeled roots in contrast to standard unpeeled beets (Edwards et al., 1989).

Excellent progress has been made in the development of smooth root germplasm (Coe and Theurer, 1987; Mesken and Dielman, 1989; Theurer, 1989). Some SR germplasm has shown as much as 60-70% reduction in the quantity of soil harvested with the roots, in comparison to standard commercial cultivars. In this paper we report results from 2 years of field tests comparing root and sucrose yield, sucrose percentage, and clear juice purity of SR experimental hybrids with those of adapted commercial hybrid cultivars.

MATERIAL AND METHODS

In 1988, three commercial cultivars (Mono-Hy E4, ACH 176, and USH 23), 3 smooth root lines, and 4 experimental CMS x SR87 hybrids (see Table 1) were planted in a field of Brixbiro fine sandy loam soil near Breckenridge, MI. The same 10 entries, with one exception, were planted again in 1989 on another farm in the same locale. A European commercial variety, Univers, which had been selected for low soil tare at harvest, was included in the test in 1989 in place of one of the SR lines. The field trials each year consisted of 10 entries planted in a randomized block design with 6 replications. Individual plots were 2 rows, 71 cm (28 in.) apart, and 9 m (30 ft.) in length. Five weeks after emergence, plants were thinned 20-30 cm (8-12 in.) apart within the row. Harvest was made November 18, 1988, and October 16-17, 1989, by means of an experimental

Table 1. Means for root yield, sucrose yield, sucrose percentage and clear juice purity for SR lines, commercial cultivars and experimental SR hybrids at Breckenridge, MI. 1988.

VARIETY	RWSA lbs.	RWST lbs.	TONS/ ACRE	SUCROSE %	CJP %
Smooth Root Lines					
85700	6402 cd†	249.7 cd	25.6 abc	15.13 de	93.50 abcd
SR87	6682 bcd	243.1 d	27.5 ab	14.86 e	93.11 cd
85131-16	6309 d	263.9 bc	23.9 c	16.09 bc	93.02 d
Commercial Cultivars					
Mono Hy E4	7609 a	298.6 a	25.5 abc	17.80 a	93.94 abc
ACH 176	7207 ab	290.7 a	24.8 bc	17.31 a	94.07 ab
USH 23	6798 bcd	275.7 b	24.7 bc	16.37 b	94.33 a
Experimental SR Hybrids‡					
WC87016	7109 abc	264.3 bc	26.9 ab	15.86 bc	93.88 abcd
WC87017	6820 bcd	258.7 c	26.4 abc	15.59 cd	93.68 abcd
WC87018	6121 d	257.8 c	23.8 c	15.50 cde	93.79 abcd
WC87019	7224 ab	256.0 cd	28.2 a	15.55 cd	93.32 bcd
Mean	6828	256.8	25.7	16.01	93.66
LSD 0.05	681	13.3	2.4	0.62	0.78
CV	9	4.3	8.2	3.35	0.72

†Means in a column with the same suffix letter are not significantly different at $P=0.05$ by Duncan's multiple range test.

‡Hybrid description: WC87016 - (SP6926-01 x FC 607) x SR87
WC87017 - EL 36C2 CMS x SR87
WC87018 - SP85576-01 x SR87
WC87019 - SP85657-01 x SR87

mini-harvester with puller wheels and a series of rotating star rinks similar to those on a conventional sugarbeet harvester. All beets in each plot were bagged and transported to the Bean and Beet Research Farm tare laboratory near Saginaw, MI. The soil was removed by hand from each root. Beet weight and soil weight was determined for each plot. Soil samples from the beets were taken and dried in an oven at 85 C for 72 hours to determine soil moisture content and convert the soil measurements to a dry weight basis. Each beet was scored for smoothness of root, on a 1 to 5 scale as defined below:

1. Very smooth taproot, no grooves, broad fibrous root zone
2. Smooth root, slightly grooved, narrow fibrous root zone

3. Partially smooth taproot, grooved, with heavy amount of fibrous roots along grooves, non-branching taproot.
4. Rough shaped taproot, deep grooves, heavy fibrous roots with some sprangled taproots.
5. Very rough, very deep grooved, multiple branched taproot.

A random sample of 10 beets was taken from each plot and sawed with a 10-blade Spreckels saw to obtain brei for laboratory analysis. Sugar percentage and clear juice purity were determined at Michigan Sugar Company's laboratory at Carrollton, MI by standard clear juice methods (Association of Official Agricultural Chemists, 1955). Data were analyzed with the MSTAT program developed at Michigan State University.

RESULTS

The 1988 field trial was hampered by a relatively dry spring, hot dry summer, and wet fall. There also was a loss of stand in various places in the field due to Rhizoctonia root rot. At harvest a stand count was made on each plot and an adjustment was made to correct for disease incidence. Harvest was delayed until November because of heavy rains that resulted in flooded field conditions.

Means for root yield, sucrose yield, sucrose percentage and clear juice purity percentage are shown in Table 1. Three of 4 experimental SR hybrids were equal to the commercial cultivars in recoverable sugar per acre (RWSA) and tons per acre root yield. Commercial cultivars averaged significantly better than SR hybrids in sucrose percentage (1.3%) and recoverable sugar per ton (29 lbs.). SR hybrids were equal to commercial cultivars in their clear juice purity. Yield, sucrose, and juice purity of the SR inbred lines, SR87 and 85700, were not significantly different from those of the SR hybrids. Line 85131-16 was one to two tons lower in root yield than SR 87 and 85700, but this SR inbred had significantly higher sucrose percentage.

SR87 had the smoothest root of all of the entries in the 1988 field trial with a score of 2.17 (Table 2). SR inbreds were significantly superior to the SR hybrids, and SR hybrids were significantly better than commercial cultivars in smoothness, averaging 2.27, 2.75, and 3.31 scores, respectively.

Due to the wet soil conditions in 1988, the quantity of soil harvested with the roots was many-fold higher than usually experienced at this location. About 60% less soil was harvested with SR87 roots than with the commercial hybrids. The SR hybrids averaged 413 pounds of harvested soil per ton of roots, which was 31% less than the soil amount harvested with the commercial cultivars. Relatively

Table 2. Means for average smoothness score and pounds of soil harvested per ton of beets harvested for smooth root lines, commercial cultivars and experimental SR hybrids at Breckenridge, MI. 1988 and 1989.

VARIETY	1988		1989	
	SMOOTHNESS SCORE	Lbs. SOIL/ TON BEETS	SMOOTHNESS SCORE	Lbs. SOIL/ TON BEETS
Smooth Root Lines				
85700	2.24 c†	400.7 cd	2.41 e	19.4 e
SR87	2.17 c	240.8 e	2.17 f	19.9 e
85131-16	2.39 c	524.1 bc	3.29 ab‡	41.1 cd
Commercial Cultivars				
Mono Hy E4	3.39 a	697.6 a	3.45 a	107.6 b
ACH 176	3.25 a	504.9 bcd	3.46 a	117.5 ab
USH 23	3.30 a	592.8 ab	3.45 a	128.7 a
Experimental SR Hybrids				
WC87016	2.64 b	376.7 d	2.87 d	41.3 cd
WC87017	2.91 b	418.2 cd	2.82 d	29.8 de
WC87018	2.72 b	455.1 cd	3.13 bc	56.5 c
WC87019	2.73 b	402.0 cd	2.98 cd	53.6 c
Mean	2.78	461.3	3.00	61.6
LSD 0.05	0.24	114.1	0.19	15.0
CV	7.59	22.2	5.50	17.9

†Means in a column with same suffix letter are not significantly different at $P=0.05$ by Duncans multiple range test.
‡Variety = Univers in 1989.

good stands of beets were achieved in the 1989 field trials and compared to 1988, little incidence of Rhizoctonia root rot was observed. At the end of the growing season there was evidence of some natural infection of Cercospora leaf spot with the variety Univers showing serious damage from this disease Leaves of Univers were mostly necrotic and the early dying of the canopy on this variety probably markedly reduced its root yield and sugar content.The soil was slightly moist at harvest and provided ideal conditions to evaluate entries for adherence of soil to the taproots.

Yield, sucrose percentage, and clear juice purity for the 10 entries tested in 1989 are given in Table 3. Three SR hybrids showed higher root yield than the commercial hybrids, however, these differences were not significant. One SR hybrid, WC87016, had equal

RWSA to Mono-Hy E4, the highest RWSA in the test. All of the SR experimentals were equal to USH 23 for recoverable sugar yield per acre. The commercial hybrids showed significantly higher sugar percentage and recoverable sugar per ton and were also superior to 2 of the SR hybrids, WC87017 and WC87019, in clear juice purity readings. SR inbreds were high in root weight but significantly lower in RWSA, RWST, sucrose percentage and clear juice purity compared to the commercial cultivars. For the most part the SR inbreds were also lower than SR hybrids for these traits. Univers had the lowest values of all of the entries for all five characteristics measured (Table 3).

The 2 SR inbred lines, SR87 and 85700, were significantly lower than all other entries in smoothness score and in quantity of soil harvested with the roots (Table 2). All 4 SR hybrids were significantly superior to commercial cultivars for these 2 traits. SR inbreds had 57% less soil harvested with roots compared to SR Hybrids and about 83% less than the commercial hybrids. Soil harvested with SR hybrids was only 38% of that collected with the roots of the commercial cultivars. Univers had significantly better smoothness score than 3 of the SR hybrids and about equal soil harvested with the roots as 3 of the SR hybrids. Significantly less soil (about 35) was harvested with Univers than with the 3 adapted U.S. commercial hybrids.

Data were analyzed over years for the 9 entries that were grown in both years. Significance of mean squares is shown in Table 4 for years, varieties, and variety × years interaction. As would be expected, there were significant differences for varieties for all factors measured when combined over 2 years. There was a significant difference between years for tons per acre, smooth root score, and pounds of soil per ton of beets harvested (see Tables 1 and 3). The 1989 test averaged about 3 tons more root weight than for 1988. The 1989 subjective scores for root smoothness were slightly higher than the previous year. Average soil harvested with beets in 1988 was about 400 pounds, approximately 7.5 times the amount harvested with roots in 1989 (Table 2). Weight of soil harvested with roots was the only characteristic measured that showed a significant year × variety interaction (Table 4). Significance was due mainly to the change between years for 3 entries (Table 2). SR line 85700 had proportionally far more soil on the roots at the 1988 harvest than observed in 1989. Of the commercial hybrids, Mono-Hy E4 carried the highest amount of soil on roots in 1988, but it was lowest the following year. WC87017 had proportionally lower soil weight at harvest in 1989 compared with other entries in the test.

Table 3. Means for root yield, sucrose yield, sucrose percentage and clear juice purity for SR lines, commercial cultivars and experimental SR hybrids at Breckenridge, MI. 1989.

VARIETY	RWSA lbs.	RWST lbs.	TONS/ ACRE	SUCROSE %	CJP %
Smooth Root Lines					
85700	6421 de†	235.1 d	27.3 a	14.42 de	93.03 cd
SR87	6620 cde	231.9 d	28.5 a	14.40 de	92.42 de
UNIVERS	6216 e	226.3 d	27.3 a	14.13 e	92.17 e
Commercial Cultivars					
Mono Hy E4	8487 a	293.7 a	28.9 a	17.49 a	94.04 a
ACH 176	8105 ab	294.6 a	27.5 a	17.52 a	94.15 a
USH 23	7372 bcd	267.2 b	27.5 a	15.99 b	94.05 a
Experimental SR Hybrids					
WC87016	7599 abc	251.3 c	30.2 a	15.15 cd	93.77 ab
WC87017	7098 cdc	237.7 cd	29.9 a	14.52 de	93.21 bc
WC87018	7375 bcd	266.2 b	27.6 a	15.85 bc	94.33 a
WC87019	7478 bc	250.6 c	29.9 a	15.35 bc	92.91 cd
Mean	7277	255.4	28.5	15.48	93.41
LSD 0.05	892	13.1	3.1	0.72	0.61
CV	10.5	4.4	9.3	4.03	0.56

†Means in a column with same suffix letter are not significantly different at $P=0.05$ by Duncan's multiple range test.

Table 4. Significance of mean squares for two years combined data on agronomic performance of smooth root lines, experimental smooth root hybrids, and commercial hybrid cultivars.

	RWSA lbs.	RWST lbs.	Tons/ Acre	Sucrose %	CJP %	Smooth Score	Soil/ ton
Years	NS	NS	**	NS	NS	*	**
Varieties	**	**	**	**	**	**	**
Yr × Var	NS	NS	NS	NS	NS	NS	**

*, **Significant at the 0.05 or 0.01 probability level, respectively.

DISCUSSION

Field tests of four experimental SR hybrids compared with 3 commercial hybrids showed reasonably similar responses for 2 very different growing seasons. Year 1989 could be classified as a normal season in Michigan, but 1988 was wetter than usual. Rainfall in April and May of 1988 was heavier than usually experienced, and in the fall of the year it rained for 27 consecutive days in September, leaving the soil in a flooded condition for the balance of the season.

SR hybrids had root yields essentially equal to the commercial cultivars. However, they were always lower in sucrose percentage and recoverable sucrose per ton. This same response was observed in the Netherlands by Meskin and Dielman (1989) with experimental triploid hybrids of globe shaped (SR type) × standard root type beets.

Sugar content of SR hybrids was about midway between that of the SR87 parent line and those observed for the commercial varieties. This demonstrates that additional breeding effort is needed to increase sucrose content of SR inbreds that will be used as parents of smooth root commercial hybrids. We observed slightly lower but statistically non-significant clear juice purity in the SR experimental hybrids. Meskin and Dielman (1989) reported significantly lower purity in the smooth root experimental hybrids they tested.

It has been demonstrated by Narum and Martin (1989) and Edwards et al. (1989) that peeling beet roots can remove a significant amount of the impurities that interfere with sucrose extraction. Martin (personal communication) also recently indicated that more total sugar can be extracted from a peeled beet than from a whole beet. It is reasonable to conclude from the significant differences observed in smoothness scores (Table 2) that smooth root hybrids could be more easily peeled than our currently adapted commercial cultivars with their grooved standard root type. Less root tissue also would be lost in the peeling process in proportion to the degree of smoothness of the root.

SR hybrids averaged 31% less soil harvested with roots than commercial varieties in 1988 and 62% less in 1989. SR hybrid scores and the soil per ton at harvest were approximately midway between those of their SR87 parent line and those of the commercial cultivars. Thus a hybrid developed with both male and female parentage of the SR type should have additional improved root smoothness and less quantity of soil harvested and transported with the beets.

Results of this study and those of Meskin and Dielman (1989) demonstrate that smooth root, "soilfree" hybrids could benefit both growers and processors. However, a 1% to 2% increase in sucrose percentage must be attained in current SR lines to make SR commercial hybrids a reality.

LITERATURE CITED

Association of Official Agricultural Chemists. 1955. Official Methods of Analysis (8th Edition), p. 564-568. Washington D.C.

Coe, G.E , and J.C. Theurer. 1987. Progress in the development of soil-free sugarbeets. J. Amer. Soc. Sugar Beet Technol. 24:49-56.

Edwards, R.H., J.M Randall, W.M. Camirand, and D.W. Wong. 1989. Pilot plant scale high pressure steam peeling of sugarbeets. J. Sugar Beet Res.26:40-54.

Meskin, M., and J. Dielman. 1988. Breeding sugar beets with globe-shaped roots:Selection and agronomical performance. Euphytica S:37-44.

Narum, J.A., and S.S. Martin. 1989. Impurities and sucrose in the root, peel and interior of diverse sugarbeet lines. J. Sugar Beet Res. 26:A18-A19.

Theurer, J.C. 1989. Progress and performance in development of smooth root sugarbeet varieties. J. Sugar Beet Res. 26:A25.