# Inbred Lines From Curly-Top-Resistant Varieties of Sugar Beets[1]

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All the curly-top-resistant varieties of sugar beets developed by the United States Department of Agriculture arid now in commercial use were derived by the relatively simple method of mass selection. In these commercial varieties plant populations are heterogeneous and practically all the individual beets are so strongly self-sterile that their sexual reproduction depends largely upon fertilization with pollen from other beets in the population.

The limitations of mass selection methods were realized, so an early search was made for exceptional self-fertile, curly top resistant biotypes that could be propagated by selfing (6*)[3]. Interest in the self-fertile lines was soon intensified by the discovery of male-sterile types which greatly facilitated plans for hybridization work. The male-sterility was found to be produced by maternal or cytoplasmic inheritance. Because of this non-Mendelian type of inheritance, it is possible to make combinations of parentage to produce populations, all plants of which are completely male-sterile. The details of the inheritance of male-sterility and methods of producing male-sterile populations have been discussed in a recent paper (7). A similar-type of male-sterility with similar possibilities for facilitating hybridization has been found in onions (4).

## Origin and Description of the Self-Fertile Lines

Self-fertility was first detected in strain 286 *(1)* which in 1930 was more highly resistant to curly top than any other strain tested. Strain 286 was so low in sugar, however, that it was withheld from the list of strains combined to form the original commercial variety U. S. 1 *(2)* from which most of the subsequent curly-top-resistant varieties have been developed. Self-fertilized seed from a single beet from strain 286 was designated S. L. 1167. Beets grown from S. L. 1167 seed and from $S_2$. and $S_3$ progenies were extremely uniform and always produced badly sprangled roots (figure 1).

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[3]Italic numbers in parentheses refer to literature cited.

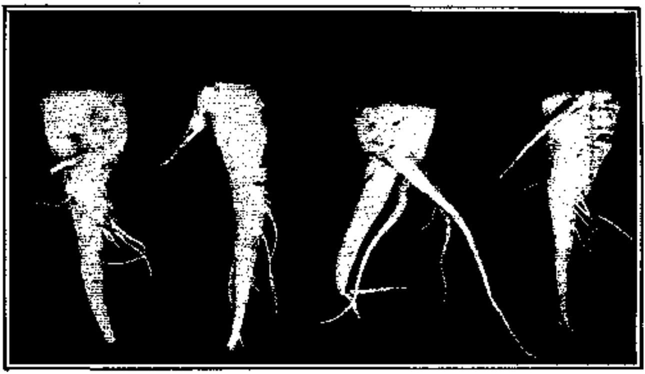

Figure 1.—Typical beets of original self-fertile line S.L. 1167, showing undesirable strangled root habit. S.L. 1167 carried a Mendelian factor for self-fertility which made inbreeding work possible. Through hybridization this Mendelian factor has been transferred to a wide variety of curly top resistant sugar beets, and all beets carrying the factor are highly self-fertile.

Hybrids with S. L. 1167 were disapointing, but after a series of outcrosses and backcrosses to the self-sterile commercial varieties some fairly acceptable inbred lines were eventually produced. Primary attention was given to the degree of curly-top resistance and all lines except those possessing the very highest degree of resistance were rapidly eliminated. The best line available in 1943 was designated CT9. The designation "CT" is intended to imply outstanding curly-top resistance. The roots of CT9 beds in the $S_1$ generation were considered too long (figure 2A), but selection in the second generation brought about considerable improvement (figure 2B).

Genetic studies *(6)* showed that the self-fertility of the inbred line S. L. 1167 was determined by a single Mendelian factor whose inheritance is governed by the rules of the oppositional hypothesis. By making tests with inflorescences placed under paper bags, self-fertility was recovered in outcrosses and backcrosses to the self-sterile commercial varieties. The CT9 beets were just as highly self-fertile as beets of the original S. L. 1167 line produced 12 years earlier.

The degree of self-fertility in these inbred lines of sugar beets is rather extreme. Even in open pollinations where these beets were surrounded by a mass of foreign pollen, the offspring were frequently

A

Figure 2.—Beets of inbred line CT9. A.—$S_1$ generation. B.—$S_3$ generation beets after selecting for shorter and more desirable root type.

sufficiently uniform to indicate complete selfing of the maternal parent. A test, in 1944 consisting of 40 *rr* self-fertile beets, open pollinated and surrounded by *Rr* and *RR* beets, showed that. 16 of the 40 beets had been completely self-fertilized. Ten additional beets showed less than 5 percent crossing and the maximum amount of crossing observed on any one beet was 14.4 percent.

With this very high degree of self-fertility it would be futile to expect sufficient natural hybridization between the inbred lines in seed fields to insure the production of hybrid seed. The use of male-sterility is the only method of obtaining hybrids between the inbred lines which appears practical.

## Male-Sterile From U. S. 22 x CT9

In 1944 the male-sterile strain S.L. 1-121, considered equivalent to the variety U.S. 22, was crossed with $S_1$ beets of the line CT9. Hybridization was accomplished in a garden isolation by using the male-sterile strain S.L. 1-121 for the female parent and the self-fertile line CT9 for the pollen parent. The hybrid population was labelled S.L. 4108.

In 1945 at Jerome, Idaho, S.L. 4108 was included with a large number of varieties grown for observation under severe curly-top exposures produced by making midsummer plantings adjacent to early planted beets in a curly top environment (5). In observation rows S.D. 4108 showed a high degree of curly-top resistance and the variety was equal in this respect to U.S. 22/3, the third release of U.S. 22 and the most highly resistant commercial variety yet produced.

Results obtained with the hybrid S.L. 4108 in 1945 at Salt Lake City under curly-top-free conditions are shown in table 1. A gain of over 11 percent in yield of sugar per acre is indicated for S.L. 4108 as compared with U.S. 22/3, and a gain of 13.5 percent as compared with the U.S. 33 variety. Five additional mass-selected varieties were included in the test with yields of sugar per acre not significantly different from those of U.S. 22/3 and U.S. 33. S.L. 4108 produced 12 percent more sugar per acre than the average of the seven mass-selected varieties.

Table 1.—Yield comparisons with the male-sterile hybrid S. L. 4108*.

| Variety and population number | Acre yield | | | |
|---|---|---|---|---|
| | Available sugar | Beets | Sucrose | Purity |
| | Tons | Tons | Percent | Percent |
| S.L. 4108 | 4.635 | 34.16 | 15.52 | 87.19 |
| U.S. 22/3 (S.L. 32) | 4.162 | 32.11 | 15.12 | 85.87 |
| U.S. 33 (S.L. 333) | 4.078 | 29.68 | 15.83 | 86.65 |
| Difference for significance, 19:1 odds | 0.205 | 1.11 | 0.35 | 0.81 |

*Test conducted near Salt Lake City, Utah, on Taylorsville loam soil type with 24 replicated plots for each of 10 varieties in the test. Single plots consisted of 4 rows 20 inches apart, 60 feet long, with yields based on weights taken from the two center rows. Two 10-beet samples were taken from each plot for sucrose and purity determinations. Turity refers to percentage of sugar on total solids. Available sugar per acre refers to: tons beets x percent sucrose x percent purity.

Approximately one-third of the increased yield from S.L. 4108 may be accounted for by superior resistance to a petiole- and crown-rot disease produced by an unknown organism which occurred in the field where the test was conducted. The other varieties suffered a loss of 1 to 3 percent of beets killed by the disease.

## Susceptible Variety x CT9

The leaf-spot-resistant variety U.S. 216 *(3)*, which is very susceptible to curly top, was crossed, with $S_2$ beets of CT9. This hybrid was compared with other varieties under a severe curly-top exposure at Jerome, Idaho, in 1945. The disease resistance of the U.S. 216 hybrid was surprisingly high (table 2). In a June 19 planting where the disease was severe enough to completely eliminate susceptible beets, the U.S. 216 hybrid compared fairly well with the variety U.S. 22/3 but was inferior to the hybrid U.S. 22/3 x CT9. In the extremely severe curly-top exposure in the July 5 planting, the injury to the U.S. 216 hybrid was more severe but disease exposures of this intensity are not commonly encountered under natural conditions. *In* many curly-top areas it is probable that this U.S. 216 hybrid would have ample curly-top resistance for commercial utilization.

Table 2.—Yield data from summer plantings at Jerome, Idaho, in 1945 under severe curly top exposures.

| Variety | | Tons beets per acre* | |
|---|---|---|---|
| S.L. number | Description | June 19 planting | July 5 planting |
| 5409 | U.S. 22/3 x CT9 | 11.29 | 4.28 |
| 32 | U.S. 22/3 | 9.33 | 2.92 |
| 5110 | U.S. 216 x CT9 | 8.91 | 1.07 |
| 1-300 | Susceptible variety† | 0.0 | 0.0 |

*Yields were taken from single two-row plots 50 feet in length.

†The susceptible variety was the popular German variety R. & G. Old Type or Kleinwanzleben E.

## Number of Germs Per Seed Ball

A search for lines with strictly single-germ or monoloeular seed balls has not yet been successful, but nevertheless there have been striking differences in degree of the multilocular condition. Observations made in 1944 among individual self-fertile beets obtained from various sources showed wide variation. In table 3 the extremely multiple condition is represented by S.L. 4704 where 90 percent of the seed balls had three or more locules. S.L. 4608 represents a decided contrast, with only 6 percent of the seed balls showing three or more locules, the remaining 94 percent of the seed balls being bilocular or unilocular. The inbred line S.L. 3555 was exceptionally bilocular. From this line 26 beets were examined during seed production. There was some variation, so the seed from five selected beets of S.L. 3555 was composited under the number S.L. 4233 (table 3) and the seed from the remaining 21 beets was composited under S.L. 4235. A high proportion of bilocular seed balls was observed in both populations with 93 percent for population S.L. 4233 and 82 percent for population S.L. 4235.

The viable germs per seed ball were observed to be considerably less than the total number of locules. For example, in population S.L. 4608 with a preponderance of bilocular seed balls (table 3) a count of seedlings grown in greenhouse soil showed that 66 percent of the seed balls produced only one viable seedling per seed ball. This high percentage of single seedlings per seed ball from a bilocular inbred line approaches the percentage of single obtained from some commercial lots of segmented seed.

Table 3.—Number of locules or potential germs per seed ball, with loeule counts based on observations of 400 seed bulls from each population.

| Population or S.L. number | Classification of seed balls | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 locule | 2 locules | 3 locules | 4 locules | 5 locules | 6 locules | 7 locules |
| | Percent | Percent | Percent | Percent | Percent | Percent | Percent |
| 4704 | 0.0 | 10.0 | 41.2 | 41.9 | 5.0 | 1.8 | 0.2 |
| 4608 | 4.7 | 89.2 | 5.7 | 0.3 | 0.0 | 0.0 | 0.0 |
| 4233 | 1.7 | 93.0 | 4.0 | 1.3 | 0.0 | 0.0 | 0.0 |
| 4235 | 2.0 | 82.0 | 12.2 | 3.5 | 0.3 | 0.0 | 0.0 |

## Discussion and Conclusions

Much has been achieved by mass selection in the development of curly-top-resistant varieties of sugar beets, but the limitations of the method are so great that the development of improved breeding methods has become imperative. The 12 percent advantage, obtained from the hybrid with the inbred line CT9, over present commercial varieties is encouraging. Only 1 year's results are available, but it is confidently expected that still better hybrids can be produced. Besides the increased vigor from the use of the hybrids with the inbred lines, much greater uniformity is possible, and this should be of major importance in the mechanization of harvest operations.

Not only has it been more feasible to obtain resistance to a major disease like curly top through the use of inbreds, but it has also been more feasible to obtain resistance to minor or more localized diseases. An example of adaptation to a localized situation is the resistance of the CT9 hybrid to a petiole- and crown-rot disease at Salt Lake City. In the same way, greater resistance to bolting is being obtained through the use of the curly-top resistant inbred lines. Results also indicate that lines with bilocular seed balls can be developed which may eventually make artificial shearing or segmenting of seed unnecessary.

The very high degree of curly top resistance now available in the $S_3$ generation of line CT9 makes it possible to consider utilization of CT9, or its male-sterile equivalent, in hybrids with varieties not, resistant to curly top, if in such hybrids increased vigor or increased sugar content can be obtained.

Sprague *(8)* states that with conventional corn breeding methods through development of inbreds, a minimum of 10 to 12 years is required for the completion of experimental testing and the release for commercial production of the best, hybrids. This consideration of time requirement emphasizes the importance of doing everything possible to hasten the development of superior inbred lines of sugar beets and of devising the most effective procedures of evaluating them in hybrid combinations.

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