Sugar Beet Types Based on Internal Morphology

ERNST ARTSCHWAGER[1]

The varieties of sugar beets grown here and abroad present a diversity of forms from the standpoint of leaf and root development, and internal structure. The types identifiable by general appearance and internal morphology may be alike or different. The intravarietal types become fewer with the approach to homozygosity in self fertile lines. This fact was brought to a focus in an earlier study on beet populations (1)[2]. Most of the varieties included in the present investigation[3] show in their internal morphology many aberrant types, but a few of the inbred lines were found to be relatively uniform.

The storage of sugar is an expression of the general metabolism, contingent on structure and subject to external and internal influences. Certain structural configurations favor or preclude sugar storage but actual analyses show that "sugar is where you find it," and that the ideal inner makeup for performance is not the same for all selections. Often apparently antithetical combinations do not preclude a high yield.

Structure of the Storage Root

The inner structure of the sugar beet root is well known; it has been described and illustrated by many investigators. Suffice it to say that the root is composed of concentric rings of vascular tissue alternating with bands of parenchyma (Figure 1A). The inner rings are mature at harvest time, more or less equidistant and relatively broad; those near the periphery are narrow and close together. In fact, in a typical mature beet root, the ratio of total radius of mature to immature rings is 10:1. The center of the beet root is occupied by a solid star-shaped body referred to as the central core. It measures only a few millimeters across but occasionally it is much thicker. Although it is quite uniform throughout its entire length, it may taper abruptly from the neck region downward. This is frequently seen in beets whose central core in the neck region is abnormally large. To distinguish the tapering core from the uniformly thick one it is necessary to check the core diameter at different root levels. The vascular rings are composed of collateral bundles in which xylem and phloem are equally broad or in which the phloem or the xylem is the more massive. The interzonal parenchyma is narrow, broad or varying in width. In the latter case the parenchyma bands between the innermost rings are usually widest.

Type Formulas Based on Internal Structure

The use of floral formulas as a short cut to description is nearly as old as the science of taxonomy. The applicability of such a "shorthand" method of recording, using vegetative characters, seemed indicated. It was successfully tried by the writer in the description of sugarcane varieties, but the description concerned itself only with the stem epidermis. The scheme is now extended to the proposed characterization of sugar beet types based on internal structure. Certain character combinations were found to be diagnostic, often recurring, and in some degree indicative of

* Senior Botanist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration.

[2] Numbers in parentheses refer to literature cited.

[3] The writer is indebted to G. W. Deming and T- O. Gaskill of the USDA Field Station at Fort Collins, Colo., and to H. L. Kohls of Michigan State College for providing the material used in this study of for making the sugar analyses.

performance. Five characters, each with three variants, are incorporated in the formulas. However, for the complete characterization of a variety additional data on structural peculiarities, color and texture of flesh, number of rings, ring density coefficient and size of central core should be recorded.

For the evaluation of characters used in the construction of the type formulas, the root is studied: 1. by viewing the cut surface of the neck region *in situ,* and 2. by examining a thin cross section of the root against a black background; both examinations are complementary. Examined *in situ,* the exposed surface may be: a. of uniform texture, b. show an indica-

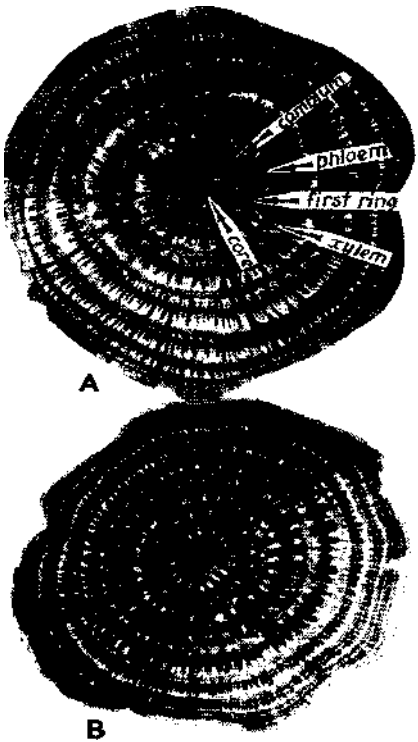

Figure 1.

tion of zonation, c. exhibit a clearly recognizable difference between vascular rings and interzonal parenchyma. Such beets usually have a grayish flesh which may appear translucent or water-soaked. If thin cross sections of the groups listed above are viewed against a black background, structural contrasts become enhanced. Thus, beets of the first group whose cut surface exhibits *in situ* a bland uniformity, reveal in section a typical though faint zonation which becomes quite pronounced in beets of the second class. Beets in the third class show such a wealth of contrast that even minor details in structure are mirrored faithfully.

The cambium of the vascular rings appears as a solid or dotted line, white or light yellow in color. In some beets the adjacent vascular tissue may also be white, giving the appearance of a broad, white cambium zone. Such white bands are commonly observed in the two innermost rings; they are less distinct and usually wanting in the others. Occasionally the white zone is so broad as to encompass most of the vascular tissue. The interzonal parenchyma of such beets has a translucent appearance which contrasts strongly with the white of the vascular zone.

List of Characters

General appearance of **the cut surface *in situ.***

1. Surface mealy white or ivory; zonation faint or absent.
2. Zonation indicated.
3. Zonation pronounced; flesh often gray and translucent.

Appearance of **thin cross section against black background.**

4. Zonation indicated.
5. Zonation pronounced; rings distinctly set off from interzonal parenchyma.
6. Rings very prominent with limits of phloem and xylem clearly defined.

Width of **vascular rings.**

7. Rings broad.
8. Rings narrow.
9. Rings variable in width; inner rings characteristically broader.

Width of **interzonal parenchyma.**

10. Parenchyma bands broad.
11. Parenchyma bands narrow.
12. Parenchyma bands of inner rings conspicuously broader.

Size of first ring.

13. Ring broad with a diameter of 22 mm. or more.
14. Rings medium large.
15. Rings narrow with a diameter of 12 mm. or less.

Type 1.

Origin: Selection SLC 78, U. S. 41.

Formula: 3-6-7-11-14.

Quantitative data: 10 rings; R. D. Coef. 2.0; sucrose 20.1 percent; weight 1.71 pounds.

Remarks: Flesh ivory gray or grayish; prominent white cambium line; small core. This type of internal structure was characteristic of about one-half of all beets studied. Its structural configuration, especially the massive phloem and the narrow bands of interzonal parenchyma, are indicative of high sugar storage. Nevertheless, many low performers fall into this class.

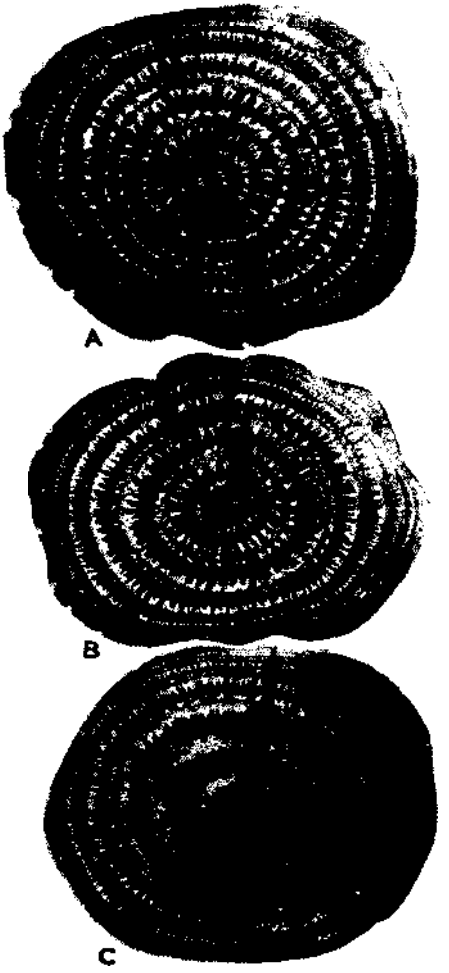

Figure 2.

Type 2.

Origin: Selection 491023-0.
Formula: 3-6-7-12-13.
Quantitative data: 10 rings; R. D. Coef. 1.82; sucrose 16.4 percent; weight 2.48 pounds.

Remarks: This is a fourth generation hybrid between mangel and sugar beet. The radius of the xylem exceeds that of the phloem; core large. The low sugar content is associated with a low R. D. Coef., massive xylem and broad first ring.

Type 3. Figure 1, A

Selection: SL 622, U. S. 22/3.
Formula: 2-6-7-11-13.
Quantitative data: 9 rings; R. D. Coef. 2.0; sucrose 14.5 percent; weight 2.16 pounds.

Remarks: Flesh ivory-cream with narrow white cambium line, massive phloem and medium large core. Indicative of higher sugar content than shown by analysis.

Type 4. Figure 1, B

Selection: SL 622, U. S. 22/3.
Formula: 2-5-8-11-14.
Quantitative data: 11 rings; R. D. Coef. 2.39; sucrose 24.4 percent; weight 1.84 pounds.

Remarks: Fine-grained ivory-white flesh; bundles within rings widely spaced; inner rings with broad white cambium; core small. The exceedingly high sugar content of this beet is associated with a high ring density coefficient, medium broad rings, and a very uniform fine-grained flesh.

Type 5. Figure 2, A

Selection: SLC 824, U. S. 35/2.
Formula: 2-6-8-12-14.
Quantitative data: 11 rings; R. D. Coef. 2.44; sucrose 17.4 percent; weight 1.37 pounds.

Remarks: Flesh white-ivory or cream; medium broad white cambium zones; small core. Indicative of higher sugar content than shown by analysis.

Type 6. Figure 2, B

Selection: SLC 78, U. S. 41.
Formula: 2-5-9-12-14.
Quantitative data: 10 rings; R. D. Coef. 2.44; sucrose 18.8 percent; weights 1.52 pounds.

Remarks: Flesh ivory-cream; broad white cambium zones, very small core; High R. D. Coef. indicative of higher sugar content than indicated by analysis.

Type 7.

Selection: U. S. 215x216/3.
Formula: 1-4-8-10-13.
Quantitative data: 9 rings; R. D. Coef. 1.95; sucrose 13.7 percent; weight 1.43 pounds.

Remarks: White flesh; large core. Low sugar content is associated with a low R. D. Coef., broad first ring and broad bands of interzonal parenchyma.

Type 8.

Selection: SL 622, U. S. 22/3.
Formula: 1 4 8 10-15.
Quantitative data: 10 rings; R. D. Coef. 2.0; sucrose 21.4 percent; weight 1.93 pounds.

Remarks: White-ivory flesh; white broad cambium zones; very small core. This type is very similar to type 7, but the sugar content is much higher.

Type 9.

Origin: Strain 1503 from U. S. 30297-0. 1936 root selfed once. 1951 beets sixth generation: self, self, self, self, sib (group 3) , self.
Formula: 2-5-8-10-14.
Quantitative data: 9 rings; R. D. Coef. 2:14; sucrose 16.4 percent; weight 2.05 pounds.

Remarks: Cream-colored flesh, narrow sharply defined cream-orange cambium; narrow bundles, broad interzonal parenchyma; large core and broad first ring.

Type 10. Figure 2, C

Selection: SLC 835, U. S. 35.
Formula: 1-4-8-10-13.
Quantitative data: 8 rings; R. D. Coef. 2.0; sucrose 18.4 percent; weight 1.48 pounds.

Remarks: Coarse flesh; gray translucent parenchyma; prominent white cambium zones; radius of phloem only slightly larger than that of xylem; large core. Structural configuration indicative of a much smaller sugar content than shown by analysis.

The following three types were selected from highly inbred lines sent to me by H. L. Kohls of Michigan State College. The type formulas are rather constant for all beets in a selection except for variation in size of core and first ring. Because of great differences in root size and shape, determination of the R. D. Coef. could not be made. Individual sugar analyses were not available and the percentage of sucrose quoted represents the average for the group as a whole.

Type 11.

Origin: Selection 57305. East Lansing, Mich.
Formula: 1-4-8-10-13.
Quantitative data: 9 rings; average core 3.8 mm.; average first ring 21.7 mm.; sucrose 15.3 percent.

Remarks: White or ivory flesh of fine texture; indistinct zonation even in section when viewed against a black background; formula constant but much variation in size of core and first ring.

Type 12.

Origin: Selection 624710; East Lansing, Mich.
Formula: 1-4-9-12-14.
Quantitative data: Average ring number 10.3; core 3.7 mm., first ring 16.1 mm.; sucrose 17.0 percent.

Remarks: Grayish vascular rings fading into darker gray interzonal parenchyma; white dotted cambium line. The higher sugar content of this type compared to type 11 is associated with a higher ring number and a smaller first ring.

Type 13.

Origin: Selection 416003. East Lansing, Mich.
Formula: 1- (4 + 5) -9-12-13.
Quantitative data: Average ring number 8.4; core 3.8 mm., first ring 19.6 mm.; sucrose 15.64 percent.
Remarks: Flesh ivory-cream, occasionally grayish; bundles within rings in discrete groups, white solid or dotted cambium line. Formula fairly constant for all roots in the selection; core and first ring very variable.

Constancy and Stability of Characters.

A character to be acceptable should be constant, well defined and stable. Most of the" types illustrated in this paper come from heterozygous populations; their characters meet only the second requirement. A study of eight highly inbred Michigan lines shows that almost all characters used in the construction of the type formulas are constant and stable. There is still much intravarietal variation in the size of the core and the first ring which may be genetic or environmental in origin. But even in regard to these characters definite tendencies are indicated. Thus, in selection 57305, the average size of the first ring for 25 individuals is 21.7 mm., while in selection 624710 the first ring measures only 16.1 mm. across.

Literature Cited

(1) ARTSCHWAGER, ERNST.
1930. A study of the Structure of Sugar Beets in Relation to Sugar Content and Type. Journ. Agr. Research 40:867-915.