Correlation Studies of Chemical and Morphological Characters of Sugar Beet Variety GW 413

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The purpose of this study was to determine the extent of any inherent association between the internal morphology and certain important chemical characters in a variety of sugar beets known to be genetically heterogeneous, from which the value of any such relationship as an aid in selection might be judged.

The material used consisted of roots selected at Billings, Montana, from GW 413, a genetically heterogeneous variety developed from a cross of two unrelated varieties followed by several generations of family selection. The roots used represented approximately the upper half of the population based on size of root with minor attention being given to appearance. For this reason, the correlation study may have particular interest to the beet breeder since he is concerned chiefly with this part of any segregating population.

The chemical characters used in this investigation included sodium and raffinose in addition to sugar and purity. Sodium and raffinose are of interest since they interfere with efficient extraction of sucrose and since both have been known to be negatively associated with sucrose.

For the evaluation of the internal morphology the type formula was employed (2, 3).[2] In addition, structural peculiarities, color and texture of flesh, number of rings, ring density coefficient, and size of central core are recorded.

List of Characters Used in the Construction of the Type Formula

General appearance of the cut surface *in situ*

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

Appearance of thin cross section in water 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.

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[2] Numbers in parentheses refer to literature cited.

Width of vascular rings

7. Rings broad.
8. Rings narrow.
9. Rings variable; 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. Rings broad with a diameter of 22 mm. or more.
14. Rings medium large.
15. Rings narrow with a diameter of 12 mm. or less.

Morphological and chemical data for roots are given in Table 1, and the correlations for some of the characters in Table 2.

Table 1.—Chemical and Morphological Data on 116 roots of Variety GW 413.

Root No.	Weight	Sucrose %	Sodium	Raffi-nose	Purity	Core Mm.	1st Ring Mm.	Ring Nos.	R.D. Coeff.	Type Formula
1	6.2	14.9	0.030	1.6	95.4	6	25	12	2.0	3-6-7-11-13
2	4.6	17.8	0.020	1.4	96.8	5	25	11	2.0	3-6-7-11-13
3	7.4	16.7	0.025	1.25	95.6	8	35	9	1.5	3-6-7-11-13
4	4.3	16.6	0.039	0.95	96.2	5	25	11	1.8	3-6-7-11-13
5	5.4	14.7	0.065	1.55	95.2	6	30	10	1.7	3-6-7-12-13
6	4.1	14.5	0.032	1.35	94.3	5	28	8	1.6	2-5/6-7/8-12-13
7	5.2	15.3	0.050	0.9	92.6	7	28	10	1.8	2-4/5-7-12-13
8	6.8	15.1	0.066	1.2	95.8	6	30	10	1.5	3-6-7-11-13
9	3.9	16.8	0.035	1.43	98.2	7	28	9	1.8	2-5/6-7-11-13
10	5.5	16.5	0.035	1.30	97.5	10	35	9	1.6	2-5-7-12-13
11	5.2	17.0	0.045	0.60	96.00	8	30	10	1.6	2-5/6-7-11-13
12	4.2	17.4	0.045	1.20	95.9	7	27	10	1.7	2-5-7-12-13
13	4.7	15.5	0.038	1.10	95.4	4	30	9	1.9	2-5-8-10-13
14	3.8	16.5	0.021	1.40	97.2	7	30	9	1.6	3-5-7-11-13
15	6.4	15.1	0.090	0.60	93.6	6	30	10	1.6	3-6-7-12-13
16	4.6	16.4	0.028	1.00	94.3	8	27	8	1.6	3-6-7-11-13
17	4.4	15.7	0.030	0.50	95.0	6	27	10	1.6	2-6-7-11-13
18	4.0	16.2	0.032	1.20	96.0	4	25	12	2.4	2-6-7/8-10-13
19	6.1	16.3	0.036	1.80	97.4	10	32	9	1.6	2-5/6-7-11-13
20	5.4	14.6	0.067	1.25	94.7	7	30	9	1.6	1-4-7/8-10-13
21	4.3	16.1	0.047	1.10	95.7	8	30	9	1.6	1/2-4-7-12-13
22	3.6	16.9	0.028	1.55	98.0	6	23	13	2.6	3-6-8-11-13
23	6.3	15.7	0.038	0.85	94.9	7	30	10	1.8	2-6-7-11-13
24	5.3	17.7	0.016	0.98	96.4	5	21	12	2.2	3-6-7-11/12-14
25	3.9	16.7	0.025	0.90	97.0	3	22	11	2.2	2-6-8-10-14
26	4.9	16.1	0.022	1.40	97.8	8	28	9	1.8	2-5-7-10/11-13
27	6.8	16.6	0.045	0.90	95.8	6	30	9	1.5	2-4-7-10-13
28	3.8	15.5	0.048	0.83	96.8	6	28	9	1.6	2-5-8-10-13
29	4.3	17.2	0.030	1.50	96.3	7	30	12	2.2	3-6-7-11-13
30	5.4	15.6	0.028	1.08	96.4	10	32	10	1.8	2-5/6-7-12-13
31	6.3	16.1	0.030	1.05	95.8	4	25	10	1.6	1/2-5-7-11-13
32	4.6	17.3	0.016	1.20	97.6	8	33	11	2.0	1/2-5-7/8-12-13
33	4.3	17.6	0.017	0.85	98.3	6	28	10	2.1	2-5-7-12-13
34	4.1	17.5	0.022	0.55	96.4	5	28	12	2.4	2-5-7/8-12-13

Table 1. (Cont.)

Root No.	Weight	Sucrose %	Sodium	Raffi-nose	Purity	Core Mm.	1st Ring Mm.	Ring Nos.	R.D. Coeff.	Type Formula
35	4.8	15.7	0.027	1.05	95.6	5	28	9	1.8	2-5-7/8-12-13
36	3.7	17.3	0.021	0.63	93.8	2	13	9	1.8	1-5-8-10-14
37	4.6	16.7	0.048	1.10	98.5	8	30	8	1.5	2-4/5-7-10-13
38	4.7	17.9	0.018	0.80	97.8	4	24	12	2.0	1-5-7/8-12-13
39	3.8	16.7	0.018	1.15	96.5	6	30	11	2.2	3-6-7-12-13
40	2.7	16.9	0.026	0.90	98.3	7	25	9	1.8	2-5-7-10-13
41	2.0	15.3	0.065	1.20	94.4	8	32	9	2.1	2-6-8-12-13
42	2.2	15.5	0.040	1.50	96.4	4	24	10	1.8	1-4/5-7/8-12-13
43	3.9	17.6	0.018	0.85	97.2	8	32	10	1.7	1-4/5-7/8-12-13
44	3.3	18.6	0.015	0.60	95.2	5	25	9	1.8	2-6-7-12-13
45	2.6	16.6	0.028	1.45	96.1	6	32	9	1.8	1-4-8-10-13
46	2.2	15.5	0.032	0.70	94.8	5	28	8	1.6	2-6-7-10/11-13
47	2.2	16.0	0.032	1.33	97.0	10	34	8	1.4	2-5-7/8-12-13
48	3.1	16.6	0.013	0.95	96.3	7	27	9	1.6	1/2-4-7-12-13
49	3.7	15.9	0.046	0.85	95.1	6	28	10	1.9	2-5-7/8-12-13
50	2.4	16.6	0.022	1.15	95.1	6	27	11	2.2	3-6-7-12/11-13
51	3.0	17.1	0.020	1.0	97.2	6	25	11	2.0	2/3-5/6-7-12-13
52	2.9	16.3	0.052	0.90	95.9	8	35	12	2.0	3-6-7-11-13
53	3.2	16.3	0.044	0.85	95.4	6	25	10	1.8	2-5-7/8-12-13
54	2.8	18.4	0.019	0.95	97.3	6	33	8	1.6	2-6-7-12-13
55	2.9	17.6	0.029	1.00	96.8	8	34	9	1.6	3-6-7/8-10-13
56	3.5	16.3	0.025	0.83	96.4	5	30	11	2.0	2-5-7/8-12-13
57	3.9	17.5	0.017	0.60	95.4	3	20	11	1.9	3-6-7-11-14
58	2.5	17.5	0.026	1.20	95.2	5	28	10	2.0	3-6-7/8-10-13
59	3.1	17.4	0.034	0.60	96.3	6	28	10	1.85	1-4/5-7-12-13
60	3.0	16.7	0.032	1.15	97.0	8	33	10	1.5	2/3-5/6-7-12-13
61	2.0	17.5	0.022	1.05	93.7	4	23	11	2.2	2-5-8-12-13
62	2.7	13.0	0.013	0.90	97.2	8	30	9	1.5	2-5/6-7-12-13
63	1.8	15.0	0.026	0.90	95.7	7	29	9	2.0	2-5-8/7-12-13
64	2.1	16.4	0.024	0.90	97.9	7	25	8	1.8	2-6-8-12-13
65	2.8	15.7	0.018	1.70	99.8	6	22	10	2.0	2-5-7-10-14
66	2.9	16.4	0.022	1.05	97.8	7	27	12	2.0	1-4-7-12-13
67	3.4	16.2	0.021	1.70	97.8	6	30	10	1.8	1-5-7/8-12-13
68	3.2	17.7	0.015	1.30	98.4	5	25	10	2.1	2-6-7/8-12-13
69	2.6	14.6	0.041	1.25	94.9	6	26	10	1.8	2-5-7/8-12-13
70	2.4	16.4	0.019	1.00	96.7	7	27	10	1.8	1-4-8-10-13
71	3.6	15.0	0.032	1.75	96.2	7	28	8	1.3	3-6-7-12-13
72	3.0	16.3	0.021	1.65	96.2	7	22	12	2.2	1-5-8-12-14
73	3.2	14.9	0.048	1.60	93.2	5	26	11	2.0	2-5-7/8-12-13
74	4.6	16.6	0.050	0.95	96.0	8	33	8	1.3	1-4-7-12-13
75	2.8	16.3	0.038	0.78	95.7	5	28	11	2.2	3-6-7-12-13
76	2.7	15.5	0.043	1.25	96.6	6	24	12	2.2	2-5-8-12-13
77	3.4	15.1	0.046	1.60	94.7	5	23	10	1.85	3-6-7-11-13
78	2.3	16.2	0.018	1.28	95.8	4	23	11	1.85	1-4/5-8-10-13
79	3.4	15.3	0.031	1.70	96.5	7	30	12	1.9	2-6-7-12-13
80	2.4	14.9	0.086	0.70	92.8	4	27	7	1.2	2-5-7-12-13
81	4.0	15.4	0.028	1.60	97.5	5	27	9	1.5	2/3-5/6-7-11-13
82	3.7	14.0	0.060	1.40	94.9	6	30	9	1.4	2-5/6-7-12-13
83	2.9	14.6	0.044	0.48	95.5	9	35	11	2.2	2-6-8-12-13
84	2.4	16.3	0.032	1.65	98.2	6	28	9	2.0	2-5-7/8-12-13
85	2.8	17.3	0.096	1.80	99.2	3	25	11	2.0	1-4-8-10-13
86	3.3	17.3	0.032	0.60	94.8	3	21	11	1.85	1/2-5-7/8-12-14
87	3.8	14.4	0.045	1.53	94.3	3	25	11	1.85	2-6-7-12-13
88	3.5	16.8	0.036	0.60	96.9	3	25	9	1.5	2-5-7-12-13
89	2.4	13.9	0.056	0.70	93.3	3	26	9	1.8	2/3-5-7/8-10-13
90	3.7	15.6	0.023	1.28	95.2	9	35	9	1.8	3-6-7-11-13

Table 1. (Cont.)

Root No.	Weight	Sucrose %	Sodium	Raffinose	Purity	Core Mm.	1st Ring Mm.	Ring Nos.	R.D. Coeff.	Type Formula
91	2.3	15.6	0.013	0.95	96.0	5	25	8	1.75	2/3-5/6-7-11-13
92	3.4	14.5	0.029	0.75	94.5	7	28	9	1.5	2-5-7-12-13
93	2.4	16.1	0.020	1.35	97.2	4	19	12	2.2	1-4/5-7/8-12-14
94	3.3	15.1	0.029	0.90	97.7	4	22	11	2.0	2-5-7/8-12-14
95	3.7	12.2	0.085	1.65	97.9	3	33	8	1.4	2/3-5/6-7-12-13
96	3.4	15.8	0.019	0.70	98.9	6	27	10	2.0	2-5-7-12-13
97	3.1	13.2	0.035	0.65	95.3	5	25	9	1.65	3-6-7-12-13
98	3.1	13.6	0.051	1.20	95.7	10	35	9	1.8	3-6-7-11-13
99	3.4	18.2	0.021	1.15	94.1	5	21	10	1.8	3-6-7-11-14
100	3.0	16.6	0.043	1.80	95.4	5	27	9	1.6	3-6-7-12-13
101	1.8	16.8	0.027	1.10	97.5	6	25	10	2.0	2-5-8-10-13
102	2.0	18.7	0.017	0.50	97.1	6	26	10	2.0	1/2-4-8-10-13
103	3.4	14.7	0.018	1.30	92.1	5	32	9	1.5	1/2-4/5-7-11-13
104	2.3	16.6	0.050	0.93	93.3	5	26	9	2.0	1/2-4-7/8-12-13
105	6.9	14.5	0.023	1.20	92.9	9	40	9	1.5	3-6-7-12-13
106	5.0	15.1	0.071	1.10	94.3	6	25	14	2.2	2-5-7-12-13
107	2.4	17.2	0.042	1.20	97.8	10	30	10	1.8	2/3-6-7-12-13
108	3.0	17.3	0.018	0.55	96.9	8	34	9	1.8	1-4-8-10-13
109	2.1	18.4	0.014	0.85	91.3	6	26	11	2.1	1-4-7/8-12-13
110	4.4	17.2	0.034	1.10	95.0	9	34	10	1.7	3-6-7-11-13
111	1.9	17.7	0.019	1.30	97.3	6	27	8	1.75	2-5-8-12-13
112	4.3	17.2	0.019	0.70	93.9	6	30	10	1.8	2-6-7-12-13
113	3.5	17.2	0.025	0.70	95.4	3	17	12	2.2	2-5-8-12-14
114	3.4	16.8	0.016	1.33	94.8	5	27	11	1.85	1-5-7-12-13
115	3.5	17.9	0.017	0.55	96.4	6	24	9	1.8	2-6-7-11-13
116	2.5	17.9	0.017	0.80	96.4	4	24	9	1.8	2-6-7-11-13

Table 2.—Correlation Coefficients for Characters Observed on 116 Roots of Variety GW 413.

	2	3	4	5	6	7	8	9
Characters	% Sucrose	Sodium	Purity	Raffinose	Core	1st Ring	Ring Nos.	Ring density coefficient
Weight	—.10	.15	—.09	.05	.18	.26	.04	—.24
% sucrose		—.52	.37	—.31	—.06	—.24	.19	.22
Sodium			—.50	.28	—.04	.22	—.14	—.30
Purity				.11	—.32	—.06	.11	.20
Raffinose					.11	.10	.05	—.01
Core						.70	—.26	—.22
1st Ring							—.34	—.39
Ring Nos.								.76

r .18 for sig. at 5% point.

Correlation Considerations

While the internal structure of the beet root as represented by the type formula and certain subsidiary characters is constant for a pure line (2) and can be used by the breeder for diagnostic purposes, the roots of variety GW 413 exhibited a great diversity of types (Figures 1 and 2). However, certain character combinations were occasionally recurring (Table 1), so that the roots could be grouped into classes of from 2 to 14 individuals.

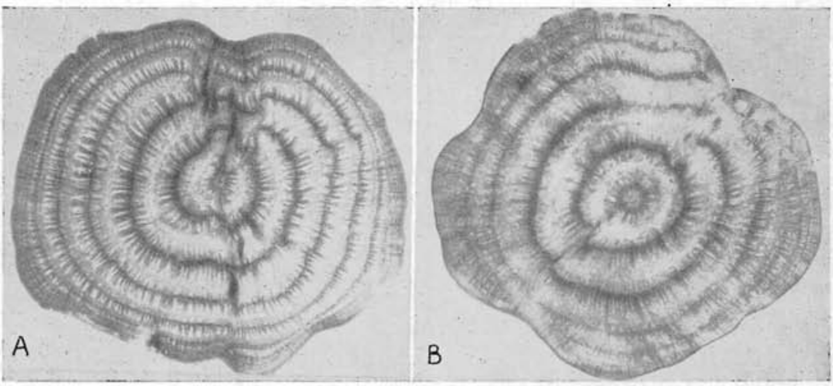

Figure 1.—*A* Root No. 77. Uniform ivory-cream flesh with very prominent bundles. Type formula 3-6-7-11-13. *B* Root No. 48. Light cream-colored flesh with long fading bundles. Type formula 1/2-4-7-12-13.

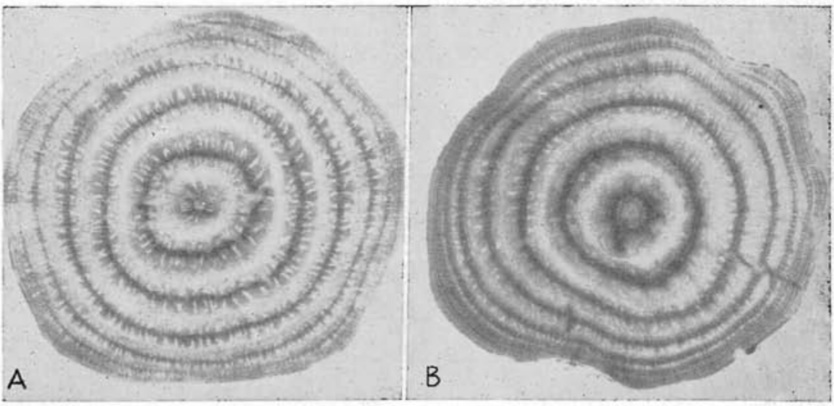

Figure 2.—*A* Root No. 13. Broad white bundle zones and somewhat watery parenchyma bands; small compact core. Type formula 2-5-8-10-13. *B* Root No. 108. Gray watery flesh with fading bundles, large compact core. Type formula 1-4-8-10-13.

Association studies showed no correlation between the different anatomical characters except that of the size of the central core with the diameter of the first ring and of the number of rings with the ring density coefficient.

As compared with previous studies using inbred lines (3), the results obtained in this investigation for chemical characters agree rather well, particularly for the negative relationship of sucrose with sodium and raffinose, and sodium with purity. Also, the absence of any significant effect of raffinose on purity for this material confirms the results with inbred lines. The obtained *r* value of .37 for sugar with purity (Table 2) is somewhat lower than expected, a corresponding value of .68 having been obtained for inbred lines (3).

The fact that the beets studied represented the upper half of the population based on size might conceivably change the size of some of the *r* values. For example, Pack (4) obtained an *r* value for weight with ring density of —.641 ± .018, whereas here the value obtained for the same relationship was —.24 with a required *r* value of .18 for significance at the 5 percent point.

Rusconi-Camerini (5) obtained a significant negative correlation between ring density and weight and a positive correlation between ring density and sucrose, but with the values varying in the E and Z types. These data are in agreement with those in Table 2.

Table 3.—Correlation Coefficient for Ring Density with Other Characters.

Character	Pack	Artschwager and Brewbaker
Weight of beet	—.641 ± .018	—.24
% sucrose	.300 ± .028	.22
Purity	.125 ± .030	.20

Summary and Conclusions

The roots used for this study were representative of the upper half, based on size, of a heterogeneous population of sugar beets. Any effective or sizeable correlation between easily observable anatomical characters and important though less easily obtained chemical characteristics could be of real value to the plant breeder. The obtained *r* value of .22 for ring density with percent sucrose and .20 for ring density with purity obtained in this study, while significant at the 5% level, are hardly sufficient to encourage the use of ring density as a short cut to improvement by selection for these characters.

Probably the principal value to be attached to these anatomical characters is in connection with their use as identifying characteristics of uniform strains, especially pure lines. Such pure lines differ very greatly in these respects and the fact that roots and lines can be catalogued accurately for these characters has been demonstrated in these and previous studies referred to in this paper.

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