Sugar Content in Mono- and Multigerm Sugar-Beet Hybrids, Carrying the gene m Isolated from Michigan Hybrid 18 and the Gene m from Variety U. S. 22/3.

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Introduction

The breeding work being conducted now is to substitute multigerm sugar beet varieties with the monogerm ones. The development of mono-germ varieties is connected with the introduction of gene m into several contemporary multigerm varieties. For this reason it is important to know what changes in sugar content and yield may occur when the gene m is incorporated into multigerm populations.

Methods

This problem may be solved by using the ordinary method of genetic analysis in studying F_2 and b_1 hybrids. For this purpose sucrose percent (or dry matter) must be determined in each plant in F_2 or b_1 hybrids, after which they must be planted to observe segregation for type of fruits. Because yield and sugar percentage vary considerably under environmental conditions, it would be necessary to analyze a large number of plants to obtain authentic data. For reasons of economy we could not use this method only.

The other method used consisted of grouping plants according to type of fruits and determination of sucrose percentage *in* their progeny. The seed was planted in test fields in several replications. To obtain seed for such a test, male-sterile *Mrn* plants were polinated with monogerm beets. The progeny of these male-sterile plants segregated into monogerm and multigerm plants which were again pollinated with monogerm beets. The seed from monogerm *(mrn)* and heterozygous multigerm *(Mm)* beets was harvested separately in each hybrid combination. By using this method it must be noted that fruits from monogerm male-sterile plants were monogerm and fruits from heterozygous multigerm male-sterile plants had multigerm fruits comprised of germs of two classes, monogerm *(mm)* and multigerm *(Mm)*, in the ratio of 1:1 (5)[2].

When such multigerm seed, containing germs of the two genotypes *mm* and *Mm,* is compared with genotypically uniform monogerm seed *(mm)*, the action of the gene *M* will be manifest in the average performance of beets obtained from the multigerm seed. However, the effectiveness of the gene *M* will be decreased because of its presence *in* only 50 percent of the plants.

There were three replications of both mono- and multigerm seed from seven different male-sterile hybrids. Monogerm and multigerm seed was, therefore, compared in a total of twenty-one replications.

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[2] Numbers in parentheses refer to literature cited.

It is possible to determine the influence of genes *m* and *M* upon sugar content in backcross hybrids only when the genes *m* and M originated from parental races high in sugar percentage. Male-sterile lines which carried the gene M originated from varieties differing in sucrose percentage. These varieties produced normal pollen before they were crossed to SLC 101 *mm.* Male-sterile races were pollinated, in addition to SLC 101 *mm,* by other mono-germ self-fertile lines high and low in sugar content.

Use of the Gene m Isolated from Michigan Hybrid 18 and from a Curly-Top-Resistant Variety U. S. 22/3

The monogerm inbred lines used as pollinators were both high and low in sugar content. The monogerm inbred line SLC 101, similar to the majority of the new monogerm lines obtained from crosses with this original monogerm line, was high in sugar. Therefore, it was also necessary to include in the experiment hybrids with low-sugar lines SL 602 *mm* and SLC 609 *mm* which carried in their genotype one gene m from the curly-top-resistant strain SL 92 (a selection from the commercial variety U. S. 22/3, very high in curly-top-resistance) . From more than a thousand F_1 plants, derived from crosses of SL 92 to SLC 101 *mm,* V. F. Stvitsky found in 1950 an F_1 line consisting of monogerm and multigerm plants. The monogerm plants from this F_1 line remained consistently monogerm in F_2 and F_3. generations. At the same time these monogerm hybrids showed a great diversity of curly top resistance, sucrose percentage and yielding ability in F_3 lines. These lines were used also in the above experiment.

Monogerm plants could occur in F_1 only when the multigerm parent involved in the crosses with SLC 101 *mm* was heterozygous for the gene *m.* In this manner monogerm F, plants were obtained which carried one *m* gene from Michigan Hybrid 18 and another *m* gene from SL 92. A study of the constancy of the monogerm character in F_2, F_3 and F_4 generations showed that these two *m* genes did not produce a difference in type of fruit or inflorescence, but the linkage with genes determining sugar content was probably different, as we shall see later.

Experimental Results and Discussion

Sucrose and Yield in Beets Grown from Multigerm and Single-Germ Fruits Collected from Multigerm Plants of the Same Hybrid

In many hybrids multigerm heterozygous *Mm* plants bear multigerm and single-germ fruits. It was important to study both kinds of fruits because their germs contained the same genotype. Therefore, differences in quality of beets would be caused only by differences in the fruits themselves.

Table 1.—Comparison of Beets Grown from Mono- and Multigerm Fruits of the Same Heterozygous Multigerm *Mm* Plants.

Type of fruit	Number replicated plots	Sucrose percent	Na p.p.m.	N per cent	K p.p.m.	Plants per plot	Tons per acre	Lbs. sugar per acre	Percentage basis Sucrose	Percentage basis Tonnage	Percentage basis Sugar per acre
Multigerm	9	15.56	682	0.30	3688	73.0	23.8	3703	100.0	100.0	100.0
Single germ	9	15.22	704	0.28	3599	69.2	23.6	3592	97.8	99.1	97.0

Such multigerm and single-germ fruits were tested in nine replications (Table 1) . No significant differences *in* sucrose percentage or in tonnage were observed.

Sucrose Percentage in Beets Grown from Multigerm and Monogerm Fruits of Backcross Male-Sterile Hybrids

Experiments conducted with single-germ and multigerm seed (such as the numerous experiments with segmented multigerm seed) give us reason to believe that the mono- or multigerm fruits themselves give no significant change in productiveness of beets. When multigerm beets are substituted for genetic monogerm beets, other characters may be changed because of possible linkage of the gene *m* with other genes. Such linkages are indicated for two characters, early or late-bolting tendency (4 and 5) and curly top resistance versus curly top susceptibility (7) . The pleiotropic effect of gene *m* on other characters was observed only for the type of inflorescence (4) , and in a slighter degree for the size of germs (6) . Increase in weight of germs in monogerm beets may influence tonnage and sucrose percent, but since sugar content and yield are controlled by special genes, a great pleiotropic action of gene *m* on these characters cannot be expected (3) .

The large diversity in sugar content and yield in monogerm lines and hybrids obtained from crosses of monogerm beets to diverse multigerm races can all be regarded as an indirect indication that genes *M* and *m* themselves do not cause big alterations in the characters mentioned. The genetical diversity in monogerm lines is so large that when these lines were used for pollination of male-sterile beets the distinction in sucrose and yield in Fj hybrids was not less than between varieties of E and Z types.

In our experiment, for example, the hybrid with the monogerm line SLC 602 which showed the highest yield exceeded in yield of gross sugar the commercial variety U. S. 22/3. The hybrid with the monogerm line,

Table 2.—Combining Ability of Four Monogerm Inbred Lines.

	Number of replications	Sucrose	Na	Amino[1] N	K	Beets per plot	Average wt. of roots	Beets per acre	Sugar per acre
		Percent	p.p.m.	Percent	p.p.m.	No.	Pounds	Tons	Pounds
				(Two ZZ lines)					
Male sterile x SLC 600 *mm*	6	16.26	509	0.28	3,213	59.5	2.08	18.3	2,975
Male sterile x SLC 175 *mm*	6	15.87	661	0.37	3,475	56.2	2.17	18.0	2,767
				Two E-type lines)					
Male sterile x SLC 602 *mm*	3	14.53	764	0.26	3,462	81.7	2.40	29.0	4,214
Male sterile x SLC 609 *mm*	6	13.10	1,018	0.21	3,844	76.6	2.47	27.9	3,655
				Commercial multigerm variety					
U. S. 22/3 (SL 96)	3	13.97	663	0.32	3,444	84.0	2.52	28.8	4,023

[1] Amino nitrogen was determined by the Stanek-Pavlas method using the spectrophotometer as an absorption instrument. The "amino N percent" values reported are based on the concentration of plutamine necessary to produce the same color. True "amino N percent" would be 0.097 times the values given.

SLC 175, which had the highest sucrose percent, hardly reached 75 percent of the yield of gross sugar of U. S. 22/3 (Table 2). The combining ability of four monogerm lines which was established in the given experiment concurred with characteristics of these lines obtained by F. V. Owen, G. K. Ryser, A. M. Murphy and C. H. Smith in F_1 hybrids between these lines and male-sterile multigerm beets (unpublished data). In their experiments the monogerm lines SLC 609 and SLC 602 produced hybrids higher in tonnage, while the hybrids obtained from monogerm lines SLC 175 and SLC 600 showed lower yield but higher sucrose.

Probably the main reason for the difference in sucrose percentage between mono- and multigerm plants of the same hybrid is the linkage of genes. Therefore, in those hybrids where gene *m* is linked with a gene causing low sucrose percent, the monogerm segregates may not be higher in sugar than the multigerm, but in the hybrids in which gene *m* is linked with a gene causing high sugar percentage, the monogerm segregates may exceed the multigerm segregates in sugar content.

In hybrid N 41-42, derived from a heterozygous *Mm* plant crossed to low-sugar line SLC 609 *mm* and in two other hybrids in which the gene *M* originated from high-sugar varieties (Klein Z and U. S. 35/2), the multigerm segregates were higher in sugar than the monogerm. When the same male-sterile lines were crossed to the high-sugar line SLC 600 *mm*, the sugar content in F_1 hybrids was increased (Table 2).

In four hybrids derived from crosses in which the monogerm parent was higher in sugar, the multigerm segregates were a half percent lower (but not statistically significant) in sugar than the monogerm (Table 3).

Table 3.—Sucrose Percentage in Mono- and Multigerm Hybrids and the Origin of Gene *m* in These Hybrids.

MS Hybrid Number	Varieties and inbreds from which the gene *m* originated	Number replicated plots	Sucrose percentage: Monogerm hybrids	Multigerm hybrids	Difference: Observed	For 5% point of Sig.
	Pollinators (low-sugar monogerm inbreds)					
4142	SL 609 *mm* (gene *m* derived from SL 92)	3	13.00	13.20		
4748	SLC 521 *mm* (SL 92 x SLC 101 *mm*)	3	14.97	15.50		
6463	do.	3	14.97	16.10		
	Total	9	14.31	14.93	.62	.83
	Pollinators (high-sugar monogerm inbreds)					
5354	SLC 175 *mm*	3	15.40	15.33		
4546	SLC 101 *mm*	3	15.17	14.37		
5051	SLC 512 *mm* (U. S. 35/2 x SLC 101 *mm*)	3	15.83	15.37		
5057	do.	3	15.83	15.20		
	Total	12	15.56	15.06	.50	.83
Difference between low-sugar group and high-sugar group			1.25	0.13		
Difference for 5% point of significance			1.10	1.20		

Comparing monogerm hybrids from the two groups (Table 3) , the sucrose percentage from the high group is 15.56 as compared with 14.31 from the low group. This difference (1.25 percent) exceeds the calculated difference (1.10 percent) required for the five percent point of statistical significance.

Sugar percentage in beets is caused by several genes belonging to different allelomorphs (3) . Therefore, complete linkage between theallele *M-m* and high sugar content cannot be expected. This is obvious from the study of segregation in F_2 hybrids between SLC 101 *mm* and multigerm fodder beets (Table 4) . Differences in dry matter between mono- and multi-germ segregates barely reached an average of 1.5 percent, while the difference between the parental plants was about 8 percent in dry matter.

Table 4.—Results with Fa Hybrids Between Multigerm Fodder Beet and Monogerm SLC 101 *mm*.

Type of fruit	Number of plants with the following percent of dry matter: 12	13	14	15	16	17	18	19	20	21	Total plants	Dry matter
												Percent
Monogerm			2	1	2	8	4	3	1	1	22	17.31 ± .37
Multigerm	2	3	7	15	13	7	7	3	4		61	16.00 ± .25

Summary

Beets grown from single-germ and multigerm fruits having the same genotypes with respect to genes Af and *m,* taken from heterozygous *Mm* plants, did not show evident differences in sucrose percentage.

New monogerm lines obtained from hybridization of the original monogerm line SLC 101 *mm* to multigerm curly-top-resistant varieties are often good in sugar. This advantage in sugar content observed in monogerm beets may have been caused by the linkage of a *M-m* allelomorph with one allele, determining the percentage of sucrose in beets, but not by a general pleiotropic action of the gene *m* itself.

Many recessive homozygous genes in beets, as in other plants, have a negative selective effect (1 and 3) . Similar genes are, for example, the genes pi (plantaginifolia) , bl (black root) , re (reduction of leaf blades) , genes causing chlorophyll deficiency, etc. Fortunately, the gene *m* does not belong in a class with such genes. The gene *m* itself cannot cause a wide variation in sugar content or in yielding capacity. These characters are controlled by special genes which are responsible for the differences in sucrose and yield between E and Z types sugar beets, fodder beets and other beet varieties.

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