Relation Between the Weight of Fruit and Weight of Germ in Mono- and Multigerm Beets

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Introduction

The quantity of monogerm seed planted per acre must not be large and must not surpass the quantity necessary for normal beet stands to avoid hand thinning. At the same time, the planting must have a normal stand of desirable thickness. To provid for a good proportional stand, the monogerm seeds must have good germinating ability and give strong vigorous seedlings. Improvement of seed quality has not been successful in previous breeding work because it is impossible to breed for this character in multigerm beets, but now the improvement of beet seeds becomes a real possibility because of the presence of monogerm beets.

Selection for size of fruit requires knowledge of the interrelationship between the weight of the fruit and the weight of germ produced within it. The beet seed is surrounded by hardened pericarp tissue and it is difficult to take it out without damage. It was necessary to work out a method which would permit taking, out the seeds from the fruits without injury.

Method

Different methods of treatment of fruits were studied. The best results were obtained by a method of hydrolysis with hydrochloric acid. For this purpose 100 fruits were placed in a test tube filled with a solution of hydrochloric acid and held in an oven at 50° C. for eight hours. The concentration of hydrochloric acid applied was 4 to 5 percent. After the acid treatment the fruits were rinsed in water for three minutes and placed again in the oven to dry at 45-50° C.

The germs were removed from the fruits after shaking the small paper envelopes in which they were enclosed or by crushing the pericarps by light knocks with a flat hammer. The fruits were placed between two layers of thin cloth for crushing.

Investigation of all samples must be conducted under the same conditions. Precautions must be taken not to keep the fruits too long in hydrochloric acid, and in applying higher temperatures. Under such conditions the process of hydrolization may go too far and the germs may be damaged. High temperatures must be avoided also when the fruits are dried. Temperatures which are too high may destroy the organic substances of the germs or they may even be burned. The ovary in beet fruits sometimes contains two ovules instead of one, or two embryos can develop from two embryo sacs in the same ovule (5) [2]. Such twin germs and germs with two embryos differ in shape from ordinary germs. They were excluded from these experiments.

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Material

Seventy F_3 and F_4 monogerm inbred lines obtained from hybridization of SL 101 *mm* with different American and European multigerm varieties were involved in the investigations. The fruits from monogerm and multi-germ plants were compared within the same F_2 hybrid populations obtained from crosses of SL 101 *mm* with multigerm sugar beets and also in different MS backcross hybrids.

The majority of cytoplasmic male-sterile lines used in these investigations were selected in hybrids derived from crosses of male-fertile sugar beet varieties to SL, 101 *mm.*

Experimental Results

Interrelation Between Number of Flowers in the Flower Cluster and Weight of Fruits and Germs.

In multigerm sugar beet populations the size of the seed ball increases with the number of flowers in the flower cluster (7) , whereas the average weight of single flowers in the cluster decreases. Parallel with this decrease in the average weight of the flowers, there is also a decrease in the weight of germs (see Table 1) .

Table 1.—Weight of 1,000 Germs and Fruits in Single Germ, Double-Germ and Multigerm Fruits from Multigerm Beets.

Hybrid number	Number of flowers in flower cluster of multigerm beets			
	1 flower	2 flowers	3 flowers	4 flowers
	grams per 1,000	grams per 1,000	grams per 1,000	grams per 1,000
Multigerm sugar beet SL 92				
Fruits	10.5	23.6	29.7	36.0
Ave. weight of single flowers	10.5	11.8	9.9	9.0
Germs	1.47	1.59	1.34	1.21
Heterozygous (Mm) Sugar beet				
350 Fruits	12.3	23.0	30.0	
Ave. weight of single flowers	12.3	11.5	10.0	
Germs	2.20	2.16	1.83	
344 Fruits	10.2	22.9	29.1	36.7
Ave. weight of single flowers	10.2	11.4	9.7	9.2
Germs	2.00	2.13	1.83	1.76
345 Fruits	9.6	17.0	26.0	
Ave. weight of single flowers	9.6	8.5	8.8	
Germs	1.85	17.3	16.6	

It must be noted that the individual flowers in one seed ball of multigerm beets contain germs of different weights (1, 3, 4, *9,* 10). Small and large germs may be observed in the same seed ball. The larger germs cannot be separated for use as planting material by contemporary methods of segmenting and seed cleaning.

The ordinary multigerm sugar beet varieties sometimes develop single germ fruits at the ends of flowering branches. The flowers located on the ends of branches flower later than the flowers situated in the middle or

at the base of the inflorescence. The fruits which develop at the ends of the branches are always smaller than the fruits at the lower portions of the inflorescence. Therefore, single germ fruits from multigerm beets always have a lower weight than fruits from double-germ or multigerm seed balls.

The same interrelation between the number of flowers in the flower cluster and the weight of fruits, and the germs developed within them, pertains to heterozygous *Mm* plants (see Table 1) . In heterozygous *Mm* plants the number of flowers in a flower cluster increases in proportion to the increase in the weight of the fruits. Multigerm fruits from these plants with three and four flowers contain lighter germs than monogerm or double-germ fruits.

Interrelation Between Weight of Fruits and Weight of Germs in Monogerm Inbred Lines

Monogerm inbred lines are distinguished not only by a different shape of fruits, but also by the size of fruits. The weight of 1,000 fruits in monogerm lines with large fruits reached 25-30 grams or more. In lines with small fruits—the weight of 1,000 fruits varied from 6 to 10 grams (see Table 2). The extreme deviation *in* the weight of 1,000 fruits reached a ratio of 1.3 or a higher ratio in different monogerm lines.

Table 2.—Frequency Distribution Showing Correlation Between Weight of Fruits and Germs in Different Monogerm Sugar Beet Lines.

Weight of 1,000 fruits in grams	Weight of 1,000 germs in grams 1.00	1.25	1.50	1.75
	2.00	2.25	2-50	2.75	3.00	3.25	3^50	3^75				
25											1	
24									1			
23										1		
22									1		1	
21								3				
20							1					
19							1		1			
18							1	1				
17						2	3	1				
16					2	2	4					
15			2	2	5	1						
14			4	5	6							
13			1		1							
12	1	1	2	3								
11	2	5	2		1							
10		3										
9												
Total Plants	3	9	11	10	15	5	10	4	3	1	2	

A study of germ weight in S_2 and S_5 inbred lines derived from crosses of SL 101 *mm* to different American and European multigerm varieties also showed a large variation in the weight of germs. One thousand germs in lines with large fruits weighed more than three grams. At the same time one thousand germs from the lines with small fruits hardly exceeded one gram (see Table 2) .

A study of the interrelation between weight of fruits and germs in the same *mm* lines indicates that both of these characters are closely correlated. When the lines with large fruits are selected, large germs are selected at the same time. The coefficient of correlation between these characters was r = 0.949.

Weight of 1,000 Germs in Monogerm and Multigerm Sugar Beet Plants from the Same F_2 Populations

The fruits of 46 F_2 plants derived from one selfed F_2 plant and grown together in the same field were harvested separately in 1952. This F_2 hybrid originated from crosses of SL 101 *mm* to multigerm sugar beets and consisted of 13 monogerm and 33 multigerm plants (7) . The weight of 1,000 fruits and germs was studied separately in each of these plants (see Tables 3 and 4) . The fruits of F_2 plants repreesnt F_3 lines. Progenies from multigerm plants had heavier seed balls in comparison with progenies from monogerm plants (see Table 3) . The weight of 1,000 fruits in monogerm beets harly reached 81 percent of the weight of fruits in multigerm beets. In spite of this the weight of germs in monogerm progenies proved to be higher than in multigerm segregates. The germs of monogerm plants were 25 percent heavier than the germs from multigerm plants in the same hybrid.

Table 3.—Segregation for Weight of Fruits and Germs in an F2 Hybrid Between Monogerm and Multigerm Beets.

Weight of 1,000 fruits in grams	Weight of 1,000 germs in grams															
	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6
18								1	2	1							
17																	
16																	
15																	
14							1		2	1	1						
13						2	1	1	2				1	1			
12						4	1		2	2	1					1	
11							1	2				1	1				
10			1					1	1	1	1		1	3	1		
9											1	1					
8																	
7									1								

[1] The monogerm plants are indicated by italicized figures.

Weight of 1,000 Germs in Mono- and Multigerm Beets in Male-Sterile Backcross Hybrids

The most exact method of establishing the influence of the gene m upon the weight of germs consisted in a study of backcross hybrids. Different male-sterile hybrids heterozygous for the gene *m* were pollinated by monogerm beets. The backcross hybrids obtained in this way segregated for mono- and multigerm plants in a 1:1 ratio. Seeds of plants which formed these two classes were harvested and analyzed for their weight. Usually every class consisted of 15 to 30 plants which produced several pounds of seed. The results for weight of seeds in mono- and multigerm beets during 1952-53 are presented in Table 5.

Table 4.—Variation of the Weight of Fruits and Germs in Mono- and Multigerm Plants In An F_2 Hybrid Between Mono- and Multigerm Beets.

	Weight of 1,000 fruits in grams												Total No.	Average weight	
	6	7	8	9	10	11	12	13	14	15	16	17	18	plants	Grams	Percent
Multigerm plants (MM+ 2Mm)				1	3	3	10	7	5			4		33	12.978 ± 0.40	100.0
Monogerm plants (mm)		1		1	6	2	1	2						15	10.46 ± 0.45	81.2

	Weight of 1,000 germs in grams													Total No.	Average weight	
	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	plants	Grams	Percent
Multigerm plants (MM+2Mm) 1			6	4	5	9	4	4							33	1.724 ± 0.3	100.0
Mongerrn plants (mm)						2	1113		2	2		1		13	2.161 ± 0.6	125.3	

In backcross hybrids, as well as in F_2 hybrids, monogerm plants produced heavier germs. The increase in weight of germs in monogerm plants over that in multigerm plants was 24 percent in 1952 and 30 percent in 1953.

Table 5.—Weight of 1,000 Germs in Mono- and Multigerm Plants in Male-Sterile Backcross Hybrids.

Year	Hybrid No.	Origin of parents: Cytoplasmic (*Mm*) male steriles	*mm* S_3 pollinator	Weight 1,000 germs in grams: Monogerm *mm*	Multigerm *Mm*
1952	50	Janash	SL 92 x SLC 101	2.32	2.12
	49	do.	do.	2.59	2.10
	45	do.	do.	2.75	1.97
	48	U. S. 22/3	U. S. 22/3 x SLC 101	2.40	1.81
	47	Klein ZZ	SL 92 x SLC 101	2.85	2.40
Average weight in grams				2.58	2.08
Average weight in percent				124.03	100.00
Standard Error in grams				0.10	0.307
1953	79	Janash	SL 92 x SLC 101	2.14	1.58
	80	do.	do.	2.23	1.55
	76	do.	do.	2.30	2.05
	78	Klein ZZ	do.	2.14	2.01
	82	Janash	do.	2.36	1.65
	84	Klein ZZ	do.	2.61	2.16
	89	Janash	do.	2.97	1.70
	87	do.	do.	2.56	1.95
	81	do.	do.	2.95	1.88
Average weight in grams				2.384	1.836
Average weight in percent				129.8	100.00
Standard Error in grams				0.085	0.074

In Table 6 the weight of fruits and germs is shown in homozygous monogerm plants in comparison with the weight of fruits and germs of single germ fruits developed on multigerm heterozygous *Mm* plants. In all hybrids the fruits from monogerm homozygous plants were larger than the single germ fruits from heterozygous *Mm* plants, and the germs in the fruits of monogerm plants were heavier than the germs from single germ fruits *in Mm* plants.

Table 6.—Average Weight of Monogerm Fruits in Monogerm homozygous Plants and of Single-Germ Fruits Separated from the Seed Balls of Heterozygous *(Mm)* Multigerm Plants in the Same Male-Sterile Backcross Hybrids.

	Monogerm fruits from homozygous monogerm plants		Single-germ fruits from heterozygous plants	
	Wt. in grams of 1,000		Wt. in grams of 1000	
Hybrid No.	Fruits	Germs	Fruits	Germs
350	15.7	2.32	**12.3 9.6**	2.20
345	12.0	**2.75**	**10.2**	**1.85**
344	18.6	2.59		2.00
Average	15.43	2.55	**10.7**	2.02
Standard Error	1.90	**0.13**	0.82	**0.10**

Conclusion

Germs were taken from the fruits after hydrolysis by hydrochloric acid for analysis of their weight. Increase in weight (also size) of seed balls in multigerm beets was caused mainly by the increase in the number of flowers *in* the flower cluster, but the average weight of germs decreased as the number of flowers in the flower cluster increased.

In monogerm beets the weight of germs increased in proportion to the size of fruit. This regularity was established by a study of weight of fruits and germs in F_2 populations and in backcross hybrids, as well as in different inbred lines obtained from crosses of monogerm beets to different multigerm varieties. We believe that this is a general regularity for the species *B. vulgaris* L. The multigerm plants which segregated in F_2 generations developed heavier fruits than the monogerm segregates in the same hybrids, but in spite of this the average weight of germs in monogerm plants was higher than in multigerm plants.

The advantage in weight of germs in monogerm beets over that of multigerm beets was also established in male-sterile backcross hybrids.

Thus the breeding of monogerm sugar beets opens up the possibility, not only for production of monogerm varieties, but also for increasing the weight (or size) of the germs themselves.

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