Selection for the Type 0 Character in Beta Vulgaris

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Introduction

Much of the sugar beet seed grown in the United States is produced by utilization of cytoplasmic male sterility (CMS). F. V. Owen (3)[2] first reported on CMS in 1945, indicating its usefulness in obtaining commercial hybrids, and postulated that two gene pairs influenced pollen production in crosses with CMS plants. Owen (4) labeled plants with genes which caused CMS in crosses as type 0. In crossing some of these type 0 lines to CMS lines, a few pollen producing plants as well as frequent semi-male sterile plants were produced. Since predominantly self-fertile lines are used by the Utah-Idaho Sugar Company, it is important that lines used in the production of stock seed be perfect type 0. Therefore, a testing program was established to attempt to produce perfect type 0 lines.

Materials and Methods

In the fall of 1960, plants of monogerm and multigerm inbred and open-pollinated lines of sugar beets were crossed in the greenhouse with annual cytoplasmic male-sterile testers to make preliminary selections for type 0. Some of the lines crossed had been selected previously for type 0 while others had had no previous selection.

Approximately 30 plants from each line were crossed with annual CMS testers. The crossing was done by exchanging bags. Pollinator genotypes were maintained by selfing. In the summer of 1961, progeny from these crosses were grown in the greenhouse and classified for anther color and pollen production.

Originally, Owen (4) had established three classes, 0, I and II with the offspring from the "0" class being all CMS. Oldemeyer (2) used a classification having three classes, but also arbitrarily set up ten classes based on microscopic description of pollen. Owen later set up five classes as follows:

1. Anthers white, no pollen
2. Anthers off white, no pollen
3. Anthers yellow, no pollen
4. Anthers yellow, some pollen
5. Anthers yellow, abundant pollen

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[2] Numbers in parentheses refer to literature cited.

This latter classification was used in the Utah-Idaho Sugar Company testing program.

On the basis of progeny tests, type 0 pollinators were selected for further testing. In 1962, only pollinators which produced progeny classified as 1 or 2 were selected. These selected lines were crossed with annual and biennial CMS testers. In some instances selected sublines were bulked and crossed in the field isolations with several biennial CMS lines.

Several investigators have observed environmental effects upon degree of male sterility (1, 5). This interaction was investigated by indexing crosses planted at Salt Lake City, Utah; St. George, Utah; and Salem, Oregon.

Results and Discussion

Table 1 indicates the scope of the Type 0 testing program. Approximately 110 type 0 selected and non-selected populations have been evaluated for presence of the type 2 genotype.

Typical populations are shown in Figures 1, 2 and 3. These curves represent a population in which no type 0 sublines were found, (Figure 1) a population which resulted in many CMS plants but few type 0 lines (Figure 2) and a population which had relatively few semi-CMS plants and many type 0 sublines (Figure 3). With a population skewed toward non-type 0 readings

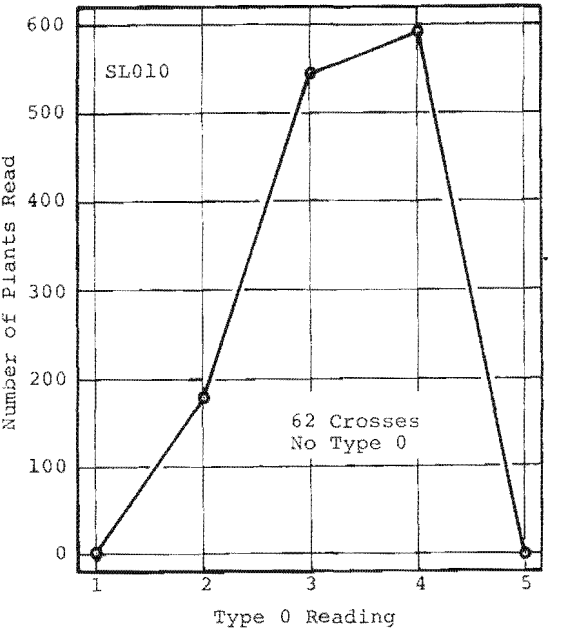

Figure 1.—Sugar beet population producing no type 0 selections.

Table 1.—Type 0 indexing of sugar beet plants for 1961 and 1962.

No previous selection	Lines indexed	Plants per line	Type 0 line	Plants sel. per line	Total progeny checked
1961	32	30	40%	5	24,000
1962	36	18	52%	3	16,000
Designated type 0					
1961	7	35	85%	10	6,000
1962	38	60	85%	20	57,000

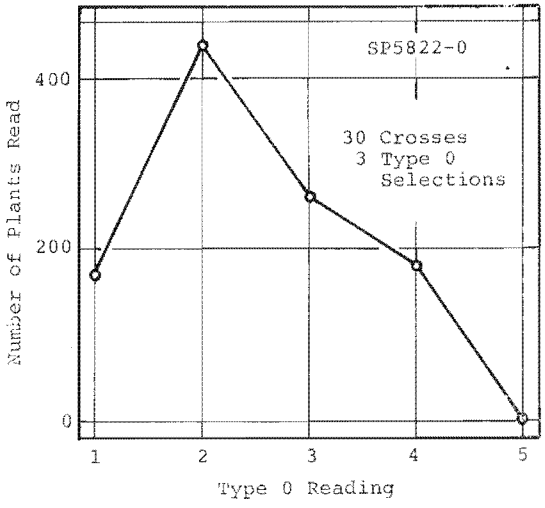

Figure 2.—Sugar beet population producing few type 0 selections.

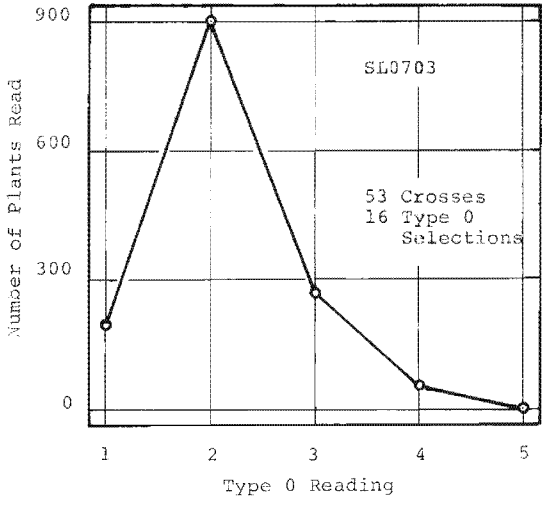

Figure 3.—Sugar beet populations producing many type 0 selections.

as in Figure 1 it is extremely difficult to isolate any type 0 sublines.

Lines, which had been released by the USDA at Salt Lake as type 0 lines, were tested again by use of an annual CMS tester (44460 H0). SL126, SL129 and SL133 plants checked for degree of male sterility were not uniform for the type 0 character. Selected sublines from these three lines were crossed to several CMS lines in field isolation plots. All three lines were improved by only one selection for type 0 (Table 2). Other lines released by the USDA such as SL127 and SL128 were exceptionally good lines. Lines developed by other breeders have been evaluated but most of the testing program concerned lines from Owen.

Table 2.—Results of further selection of sugar beets in designated Type 0 lines.

	Percent CMS			
	SL129MS	SL133MS	CT5MS	Average
SL126	94	93	91	92.6
Selected SL126	100	96	99	98.3
SL129	98	98	100	98.6
Selected SL129	100	99	100	99.6
SL133	94	92	82	89.3
Selected SL133	100	97	100	99.0

The annual CMS tester was used in 1960-61 exclusively. In the following years biennial testers were also used. Table 3 compares readings obtained with annual and biennial testers. With rigorous selection of lines, it was possible to obtain lines which, when crossed to the CMS annual, resulted in 100% male sterile plants. These same type 0 plants were crossed with six biennial male sterile lines with varying results. SL129 CMS gave results identical to the annual CMS while the other biennial crosses differed according to the particular cross made. The annual CMS is an excellent tester to screen populations for type 0 and to develop lines to cross with perfect CMS lines. The

Table 3.—Annual versus biennial male steriles for testing for the Type 0 character in sugar beets.

	44460HO	Percent CMS					
	Annual	SL126	SL127	SL128	SL129	SL133	CT5
0161	100	93	90	94	100	78	92
1861	100	95	100	98	100	98	100
2161	100	96	96	99	100	97	88
2961	100	99	100	100	100	97	98
3061	100	83	100	91	100	97	93
3161	100	100	97	87	100	74	93
3561	100	80	79	100	100	88	72

possibility exists that an annual tester carrying one or more minor modifying genes for pollen restoration could be created which would be a more critical tester than the CMS now being used.

Some sublines selected for the type 0 character on the basis of the annual tester may produce only CMS plants (Table 4).

Table 4.—Results of crossing a selected Type 0 pollinator (3061-35) with various CMS lines of sugar beet.

	Type 0 classification					
	1	2	3	4	5	Percent CMS
Annual MS	0	26	0	0	0	100
CT5 MS	26	16	0	0	0	100
SL126 MS	8	10	0	0	0	100
SL127 MS	13	2	0	0	0	100
SL128 MS	8	3	0	0	0	100
SL129 MS	8	3	0	0	0	100
SL133 MS	17	7	0	0	0	100
Original pop. × annual MS	243	927	257	34	0	80

Other sublines with equally good readings when crossed with the annual CMS may result in pollen producing plants when crossed to the same range of CMS biennials (Table 5). Table 6 shows segregation of a typical type 0 line and differences obtained by use of various CMS testers. Such interactions necessitate either the production of perfect CMS lines or the testing of all specific combinations of interest.

Table 5.—Results of crossing a selected Type 0 pollinator (2161-42) with various CMS lines of sugar beets.

	Type 0 classification					
	1	2	3	4	5	Percent CMS
Annual Ms	9	11	0	0	0	100
CT5 MS	2	5	7	3	0	41
SL126 MS	16	28	3	0	0	94
SL127 MS	11	14	0	0	0	100
SL128 MS	30	20	0	0	0	100
SL129 MS	5	21	0	0	0	100
SL133 MS	14	25	2	0	0	95
Original pop. × annual MS	134	692	352	108	0	64

Inheritance of the basic type 0 character apparently is not too complex since in populations such as SP6045, it was possible to obtain sublines which were type 0 and sublines which were non-type 0 in crosses with the annual CMS tester (Tables 7 & 8).

Table 6.—Typical variation in percent CMS in sublines of sugar beets selected for Type 0 character.

	Percent male sterile							
	126MS	127MS	128MS	129MS	133MS	CT5MS	SP6121-01	Annual MS
3161-3	.....	100					100	100
3161-10		.....	96	100	94	93		100
3161-11	100	.....		100	.....	86	.....	100
3161-15	100	.....	.....	100	31		.....	100
3161-16	100	92	46	100	52	93	.....	100
3161-31	.....	.....	.....	100	100	.....	.....	100
3161-32	100			100	72	100	.....	100
3161-46	100	100	100	100	.....			100
Average	100	97	81	100	70	93	100	100

Table 7.—Results of crossing a selected Type 0 pollinator (SP6045-4) with various CMS lines of sugar beets.

	Type 0 classification					
	1	2	3	4	5	Percent CMS
Annual	11	24	0	0	0	100
SL126 MS	23	24	0	0	0	100
SL127 MS	3	9	4	0	0	75
SL128 MS	14	15	0	0	0	100
SL133 MS	4	10	4	3	0	67
SP6121 MS	9	3	0	0	0	100
Original pop. × annual MS	92	311	193	528	32	35

Table 8.—Results of crossing a selected Type 0 pollinator (SP6045-26) with various CMS lines of sugar beets.

	Type 0 classification					
	1	2	3	4	5	Percent CMS
Annual MS	0	0	3	30	0	0
CT5 MS	0	1	1	15	0	6
SL129 MS	0	0	9	11	0	0
SL133 MS	0	0	4	37	6	0
Original pop. × annual MS	92	311	193	528	32	35

Other sublines, such as SP6045-18, produced approximately the same distribution as the original population (Table 9). Owen's hypothesis of one or two major genes seems to be generally consistent with observed results. However, it appears that a plateau is reached where the majority of the progeny are CMS, but where a few progenies are either semi-CMS or pollen producers in crosses with particular CMS lines.

Owen (3, 4) felt that minor modifying genes might affect the type 0 character and Oldemeyer (2) reported that such genes were important in CMS lines. It appears that several such

Table 9.—Results of crossing a selected Type 0 pollinator (SP6045-18) with various CMS lines of sugar beets.

	Type 0 classification					
	1	2	3	4	5	Percent CMS
Annual MS	10	20	5	34	0	43
CT5 MS	0	6	3	18	3	20
SL128 MS	2	6	19	12	0	21
SL129 MS	23	10	2	2	0	89
SL133 MS	2	18	22	37	0	25
Original pop. × annual MS	92	311	193	528	32	35

genes, having an additive action, are involved in producing a perfect type 0 line or a perfect CMS line. Table 2 shows the results obtained from selection in lines which were designated as type 0. Although these lines produced predominantly CMS offspring in crosses with various testers, sufficient semi-CMS pollinator plants remained which would have resulted in a small proportion of inbred plants in the final commercial cross. Perhaps a small number of inbred plants in commercial populations is unimportant but since perfect CMS lines and perfect type 0 lines are obtainable it seems that they should be the ultimate objective.

Table 10 presents results obtained in various reciprocal crosses. SL128 and SL127 were good lines for type 0 and CMS while SL126, SL133 and CT5 were relatively poor. In all crosses the CMS lines were rogued to white anther plants. Where the poor line was used as the CMS and rogued the production of CMS plants was always greater than for the reciprocal cross. Poor type 0 plants, of course, could not be rogued out. When two relatively poor lines were crossed the results from reciprocal crossing were almost identical. It appears possible that a CMS line might carry a minor gene for pollen restoration but still be

Table 10.—Comparison of reciprocal crosses of sugar beet for percent CMS.

	Percent CMS
SL126CMS × SL128	93
SL128CMS × SL126	84
SL133CMS × SL128	81
SLC128CMS × SL133	76
SL126CMS × SL127	87
SL127CMS × SL126	77
CT5CMS × SL127	95
SL127CMS × CT5mm	89
CT5CMS × SL128	94
SL128CMS × CT5mm	85
CT5CMS × SL133	81
SL133CMS × CT5mm	80

CMS. Therefore, it is important that the CMS line be improved as well as the type 0 line.

Several plant breeders have reported environmental effects on CMS. Table 11 shows such a location interaction in one of two years. On several stock seed lots grown in two years at three locations, the percent CMS varied considerably in 1962 but very little in 1963. In 1962, Oregon produced the lowest percent CMS while Salt Lake-grown seed was about 20% better. In 1963 this wide difference was not present.

Table 11.—Comparison of CMS in stock seed of sugar beets grown at three locations in 1962 and 1963.

	Oregon	Salt Lake	St. George
1962 stock seed			
A	62	81	83
B	57	83	71
C	61	85	59
D	80	90	82
	65.0	84.8	73.8
1963 stock seed			
D	80	86	79
E	80	84	84
F	68	68	67
G	93	95	95
H	62	53	74
	76.6	77.2	79.8

Table 12.—Comparison of five CMS lines of sugar beets crossed with various Type 0 pollinators grown at three locations in 1962.

	Percent CMS					
	SL126MS	SL127MS	SL128MS	SL129MS	SL133MS	Average
Oregon	91.5	89.0	93.0	96.2	85.5	91.0
Salt Lake	92.3	84.5	86.5	96.5	95.5	91.1
St. George	85.7	90.3	82.2	97.8	100.0	91.2
Average	89.8	87.9	87.2	96.8	93.7	

Table 13.—Comparison of five Type 0 pollinators crossed with various CMS lines of sugar beets grown at three locations in 1963.

	Percent CMS					
	SL 129	SL 133	CT 5	SL 127	SL 128	Average
Oregon	98.5	80.2	84.7	91.2	95.5	90.0
Salt Lake	97.5	92.7	90.7	88.7	90.5	92.0
St. George	100.0	83.8	91.3	97.2	96.2	93.7
Average	98.7	85.6	88.9	92.4	94.1	

Except for cross G in 1963, all of the stock seed crosses produced a relatively low percentage of CMS plants. There was a locations by cross interaction in one of the two years in which the crosses were tested. However, in crosses between good CMS and good type 0 lines there were no significant differences from one location to another in either 1962 or 1963 (Tables 12 and 13). Crosses in Oregon tended to be slightly lower in percent CMS. SL129 CMS had the highest degree of CMS and the least amount of variation from location to location.

In 1963, readings of several hundred biennial crosses were made in the greenhouse at Salt Lake City, Utah and in the field on the same crosses at St. George, Utah. Readings from these two different locations were very similar.

Summary

1. On the basis of results obtained from more than 4,100 crosses to find perfect type 0 lines, inheritance of the type 0 character in sugar beets seems to follow Owen's theory of two major genes. However, inbreeding and testing for two or more generations is important since minor modifying genes appear to play a large role in the production of perfect type 0 lines.

2. Development of perfect CMS lines also is necessary since minor modifying genes present in CMS plants interact with similar genes in type 0 plants to produce semi-CMS progenies.

3. The annual CMS tester was excellent for preliminary screening but lines designated type 0 on the basis of annual crosses resulted in semi-CMS and pollen-producing plants in crosses with particular biennial CMS lines. It may be possible to create an annual tester which will identify perfect type 0 lines.

4. Environment by line interactions appear to be important when lines are not perfect type 0 or perfect CMS. Lines which are perfect type 0 or perfect CMS do not seem to be influenced by environment.

Literature Cited

(1) HOAGABOAM, G. J. 1957. Factors influencing phenotypic expression of cytoplasmic male sterility in the sugar beet (*Beta Vulgaris* L.). J. Am. Soc. Sugar Beet Technol. 9: 457-465.

(2) OLDEMEYER, R. K. 1957. Sugar beet male sterility. J. Am. Soc. Sugar Beet Technol. 9: 381-386.

(3) OWEN, F. V. 1945. Cytoplasmically inherited male sterility in sugar beets. J. of Agr. Res. 71: 423-440.

(4) OWEN, F. V. 1948. Utilization of male sterility in breeding superior-yielding sugar beets. Proc. Am. Soc. Sugar Beet Technol. 5: 156-161.

(5) OWEN, F. V. 1950. The sugar beet breeder's problem of establishing male sterile populations for hybridization purposes. Proc. Am. Soc. Sugar Beet Technol. 6: 191-194.