The Effect of Successive Seed Increases by the Overwintering Method on the Non-Bolting Characteristics of Two Relatively Non-Bolting Varieties of Sugar Beets

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In recent years, considerable effort has been expended in California in the development of sugar beet varieties which are highly resistant to bolting or production of seed stalks. This characteristic in varieties is highly desirable for varieties to be planted during the winter months of November, December and January or even earlier. When seeding is done early enough so that bolting is heavy, yields are often reduced because of it.

Development of non-bolting varieties presents a peculiar situation. Bolting is undesirable in commercial sugar beet crops because of the yield reduction it causes, so successful efforts have been made to develop varieties highly resistant to bolting (1) (2)[2]. Bolting is essential in the seed fields, however, because it represents the reproductive phase of the beet and is necessary to maintain the variety. Therefore, if a variety were developed so resistant to bolting that plants in it were unable to develop a seed stalk, it would be useless because it couldn't be maintained, even though such a characteristic would be highly desirable in some commercial beet fields.

Some recent occurrences in early planted commercial fields have given rise to a question regarding the duration of successful maintenance of the high degree of non-bolting in varieties. In some cases it seemed as if var-ieties had deteriorated in the non-bolting quality which they apparently possessed when first developed a few generations previously.

The present method of commercial seed production in sugar beets is to plant the seed fields in August (for non-bolting varieties) , and allow the small plants to remain in the ground over winter. Seed stalks are developed and seed produced the following summer. Most of the seed used in California for planting the commercial sugar beet crop is produced in Oregon or California in this manner.

Present open-pollinated varieties are highly heterogeneous, being made up of a wide range of genotypes. Individual plants are highly self sterile so flowers are cross-pollinated. It is conceivable that non-bolting qualities might deteriorate with each successive seed increase if, for some reason, a certain percentage of plants did not produce seed stalks or participate in the reproduction of the variety. This percentage of plants not producing seed would probably be the most definitely non-bolting segment of the population, and, these being eliminated from reproduction, might cause a shift toward less bolting resistance in the variety. Examination of seed fields has failed to demonstrate this as a cause of deterioration in the non-

[1] Plant Breeder, Spreckels Sugar Company, Spreckels, California.
[2] Numbers in parentheses refer to literature cited.

bolting qualities of varieties. Many counts of plants producing seed stalks in seed fields have indicated that bolting approached one hundred percent *in* August planted fields.

Usually in seed plots it can be seen that the plants which start to bolt earliest produce the largest seed stalks and consequently are the most prolific. if these early bolting plants constitute that segment of the population which is inherently the least bolting resistant, then it is conceivable that a de-terioration in non-bolting qualities of a variety could occur through succes-sive seed increases even though all plants produce seed stalks. This would seem to be a reasonable result of natural selection in varieties highly re-sistant to bolting.

To test the amount of deterioration in the non-bolting characteristics of sugar beets a field test was designed to include successive generations of two varieties. Four successive seed generations without selection were available from the varieties U. S. 56/2 and U. S. 75. Each increase of both varieties was produced in Oregon. U. S. 56/2 originated as SL659, and suc-cessive increases were numbered SL759, SL859 and U. S. 56/2, respectively. U. S. 75 originated as C975 and successive increases were numbered C075, CI 75 and U. S. 75, respectively. Table 1 shows the succession of increase of each variety, the parentage, and the year in which each increase was made.

Table 1.—Showing Parentage and Year of Seed Production of Four Successive Seed Generations in the Two Varieties, U. S. 56/ and U. S. 75.

Variety	Increased from	Year
SL659	.. [1]	1946
SL759	SL659	1947
SL859	SL759	1948
U. S. 56/2	SL859	1952
C975	... [1]	1949
C075	C975	1950
C175	C075	1951
U. S. 75	C175	1952

[1] Original selections.

The field test consisted of eight replications arranged in a randomized complete block design. Plot size was two rows fifty feet long for each variety in each replication. The entire plot was harvested for yield determination. Counts were made during the growing season of number of beets per plot after thinning, number of beets bolting and number of beets infected with downy mildew caused by *Peronospora schachtii.* A beet was considered as a bolter if seed stalk initiation was visible whether or not seed was produced. A beet was considered to be infected with downy mildew if mycelia of *Peronospora schachtii* could be detected on the leaves. The plots were planted December 16, 1952, and harvested October 29, 1953.

Table 2 shows the average percentage of bolters, yield in tons per acre and percentages of plants infected with downy mildew. The bolting per-centage of each successive reproduction of U. S. 56 can be seen to show a progressive increase. SL659, the original U. S. 56/2, showed 6.1 percent bolters, while U. S. 56/2 three seed increase generations later showed 14.4 with intermediate amounts in SL759 and SL859. With an L.S.D. at the five percent level of 3.3 and at the one percent level of 4.4, the differences shown are highly significant. This would seem to indicate that natural selection was effective during the seed increases in reducing the high degree of bolting resistance possessed by the original variety.

Table 2.—Averages of Percentages of Bolted Beets, Yields and Percentages of Mildew Infection in Successive Seed Generations of Two Relatively Non-Bolting Varieties of Sugar Beets, U. S. 56/2 and U. S. 75. (Eight replications)

Variety	Percent Bolters	Yield Tons/Acre	Percent Mildew Infection
SL659	6.1	21.79	27.5
SL759	8.3	22.68	25.6
SL859	9.6	21.59	28.0
U. S. 56/2	14.4	21.90	26.9
C975	16.2	23.60	20.1
C075	10.1	24.75	18.1
C175	12.5	22.62	17.5
U. S. 75	13.3	22.05	18.9
L.S.D. 19:1	3.3	NS	6.6
L.S.D. 99:1	4.4	NS	8.8

The trend is not so consistent in the successive generations of U. .S 75. The reduction in bolting between C975 and C075 is difficult to explain be-cause it would seem all factors of natural selection pressure would tend to increase the amount of bolting rather than to decrease it. While an error someplace in making up such a test is possible, a careful recheck of seed and method used has not located any mistake. Except for the first seed increase the pattern is similar in the U. S. 75 series to that for U. S. 56/2 in that a slight increase in bolting percentage is shown in each seed increase from C075 to U. S. 75. The difference in bolting percentage between C075 and U. S. 75 approaches but does not reach statistical significance at the five percent level. Because only the one seed increase showed a reduction in bolting and all other seed increases in both varieties showed an increase in bolting percentage with each successive generation, it is believed that it is correct to assume there is, in general, a deterioration in the bolting resistance of highly non-bolting varieties in successive generations of seed increase.

Table 2 indicates no significant differences between the yields of any of these varieties. Usually the yields are closely associated with bolting percentage in tests which are planted early enough for bolting to occur to any great exetnt. As was pointed out previously in making the counts of bolted beets in this study, any plant showing evidence of seed stalk elonga-tion was considered to be a bolter whether or not seed was produced. Many of the beets counted as bolters had very short vegetative seed stalks which were not long enough to be seen above the foliage. Thus, it is possible that bolting had not progressed far enough to be a factor in reducing yields.

The mildew percentages as shown in Table 2 indicate a rather wide difference between the two series of varieties, but essentially no differences exist between succeeding generations within either the U. S. 56/2 or the U. S. 75 series. This was expected because there is no reason to believe that mildew resistance or succeptibility should be affected by natural selection in a seed field in an area not subject to infection by downy mildew. Any exception to this may be due to close genetic linkage between factors con-ditioning resistance to mildew and those conditioning resistance to bolting.

Often, when a variety is first developed, only a small amount of seed is produced. Most of this seed may be used for preliminary evaluation tests to determine whether the strain is satisfactory for introduction as a com-mercial variety. Sometimes a seed increase of the original selection must be made before sufficient tests have been conducted to determine the value of the new strain. When a new strain is considered of enough value to become a commercial variety it is usually necessary to produce at least two seed generations to increase the seed to desired amounts.

Thus, three or four seed increases are almost always used in the transi-tion from an experimental strain to its release as a commercial variety. These early increases are usually used as "stock" seed. Stock seed is the seed from which the commercial seed crop is grown and stock seed increases are made only as the supply becomes depleted. Periodically, however, further increases of stock seed are necessary to provide adequate supplies of seed for com-mercial increases, if a variety remains in demand for a long time.

The results of this study would indicate that any way of reducing the number of seed increases of a particular non-bolting variety would help maintain the non-bolting quality of the variety. Once a non-bolting strain is found desirable enough to be increased as a commercial variety probably larger stock seed increases should be made in an effort to reduce the number of increases required. Roguing of the early bolters from stock seed fields may help to maintain the non-bolting quality of a variety but no compara-tive data are available on the value of such a proceedure. If a satisfactory method of steckling reproduction could be developed for extremely non-bolting varieties, considerably larger seed increases could be produced from a given amount of seed than by direct seeding. This would reduce the num-ber of seed increases necessary to provide the desired amount of seed.

When commercial varieties are hybrids whose component inbred lines are homozygous, this problem of deterioration in bolting resistance should be eliminated. In inbred lines, the difference in rate of bolting between different plants in a field would be due primarily to environmental differ-ences, and because of lack of genetic variability within inbred lines, any major shift in a genetic characteristic between successive generations would indeed be unlikely.

Summary and Conclusions

A test was conducted to determine the effects on the non-bolting char-acteristics of successive seed generations in Oregon on two relatively non-bolting sugar beet varieties, U. S. 56/2 and U. S. 75. Most of the evidence indicated a deterioration in the non-bolting quality of the varieties. Yields and percentages of plants infected by downy mildew caused by *Peronospora schachtii* were not influenced in successive generations. The non-bolting quality of a variety is a characteristic which would lend itself much more to natural selection than would either root yield or percentage of mildew infection.

At least three or four seed increases are required from development to commercial utilization of a variety. Suggestions to reduce either the num-ber of seed increases required or the effect of natural selection on each increase included:

> 1. Making larger stock seed increases, necessitating fewer of them; 2. a satisfactory method of steckling increases for stock seed in non-bolting varieties, because of the gain in amount of seed produced per pound seeded over the direct seeding method; 3. roguing early bolting plants in the seed field to eliminate them from seed produc-tion, and 4. the use of hybrid varieties whose component inbreds are homogygous for the non-bolting characteristics.

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