Non-Sugar Relationships in Breeding High-Purity Beets

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As part of our breeding program, we have carried on work leading to high-purity selections since 1930. Because of the time and expense involved in making large numbers of chemical determinations, the purity work has been done on a rather limited scale, as it has been one of our minor objectives. Also, we have recognized from the beginning that there is a danger in this type of selection which is similar to the danger in selecting primarily for sugar content, i.e., the danger of developing extreme types which show excellent purity of juice but which do not produce enough sugar per acre to be competitive with other varieties.

It might be well to mention here that it is very difficult to measure from one generation to the next the degree of improvement in such constituents as ash, harmful nitrogen, etc. This is for the reason that these vary widely with the season, with the soil in which the beets are grown, whether leafspot *(Cercospora betieola)* is present or not, and so on. It is therefore safest to measure the over-all improvement over a period of several generations, by comparing the high-purity varieties with the same standard.

During the past 10 years we have made thousands of determinations of both electrical resistance and harmful nitrogen on individual beets, as well as similar determinations, together with true purity, on thin juice produced from 20 beets of the same family. As a result of these studies we are now inclined to place somewhat less emphasis on harmful nitrogen than we were at the beginning, as we feel that we can make progress rapidly enough by studying ash by electrical resistance and check our work by means of true purity determinations. The situation might be different if we were interested in developing extreme types with a tendency to low yields, but we make every effort to avoid this.

Another reason for not paying too close attention to nitrogen content and harmful nitrogen content of breeding stock is the extreme variability encountered in these figures. This is indicated in the following analyses of 12 good breeding stocks.

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Family	Percentage totalN in beets	Percentage total N on sugar	Percentage harmful N in press juice	Harmful N, percentage on sugar in press juice
1	.1471	1.067	.0525	.351
2	.1366	.817	.0449	.253
3	.1261	.789	.0371	.219
4	.0915	.558	.0373	.208
5	.1173	.766	.0435	.269
6	.1341	.881	.0633	.398
7	.1062	.683	.0384	.235
8	.1383	.926	.0567	.361
9	.1355	.832	.0475	.277
10	.0981	.640	.0255	.150
11	.1135	.727	.0366	.219
12	.1275	.831	.0490	.296

The following figures give general averages for breeding stocks which give us excellent purities, both in commercial beets and in the factory juices.

Percentage on Beets

Total nitrogen	.10 percent
Harmful nitrogen	.03 to .04 percent
Percentage ash	.50 percent
Electrical resistance of juice	80 to 150 ohms

From the above it is evident that the ash content is normally about 5 times as high as the total nitrogen, and the latter is approximately 3 to 4 times as high as the harmful nitrogen.

For much of the past century there have been many investigations and speculations as to the relative importance of the various non-sugars in increasing the sugar losses in molasses. As is generally known, the chief non-sugars which affect the purity of factory juices are the following: Mineral salts or ash, harmful nitrogen not represented by betaine, betaine. organic and inorganic acids, and other organic matter.

Up to the present time no one knows the melassigenic value of 1 pound of soluble ash as compared with 1 pound of harmful nitrogen, or whether 1 pound of betaine is more or less melassigenic than the same amount of ash.

Since all of these compounds have separate and cumulative effects in keeping sugar in solution, and since they could not be separated from each other, it has been an insoluble problem to determine accurately the melassigenic effect of each major constituent. There has been much discussion and debate on this question among chemists engaged in all phases of sugar processing and refining. I am glad to say that now, however, we are rapidly developing a new laboratory tool which should throw light on this problem. By means of the selective action of various new ion-exchangers we hope to be able to produce in the laboratory the following types of molasses: Nitrogen-free molasses, betaine-free molasses, and ash-free molasses.

When I use the word free, I mean relatively free. We have already done considerable work on this subject in our research laboratory, and as time permits, we plan to study sugar solubility and final molasses purities obtainable with these unusual molasses types. If we succeed, we should then know much more about molasses, about non-sugars in beets and their relative importance from the breeding standpoint than has ever been known before. It will then be early enough to strive for the partial elimination of the particular compounds in beets which are the most melassigenic, provided that this can be done without sacrificing the maximum production of sugar per acre. In any breeding program it must of course be recognized that many of these non-sugars are essential to the metabolism of the growing beet and they must not therefore be reduced beyond a certain minimum.

Returning now to some tangible figures for the purity of various strains of beets, I might say that during the past season we have again been struck with the effect of leafspot on purity. The following is a typical comparison of our most resistant strains with our regular Great Western non-resistant yield type. The resistant strains are the result of many years of breeding, in which major emphasis was placed on resistance or ash content, but at the same time sugar content and purity were given careful consideration. The comparison was made under very severe leafspot attack in eastern Colorado.

	Percentage sugar	Purity	Res. of pressed juice (ohms)
Resistant strain A	17.4	89.8	62
Resistant strain B	17.6	88.3	82
Non-resistant G,W. Standard	14.6	86.6	43

It must be remembered that the range in both sugar and purity would have been very much less in the absence of leafspot.

Although we have not yet been able to develop maximum purity in our commercial Great Western seed, because of the time required to develop a variety which is satisfactory in every other respect as well as purity, we are gratified to report a very definite reduction in the non-sugars handled in our factories during the past 4 years, during which we have used very largely our own seed. These 4 years cover years of extreme drought as well as ample moisture, years of diseases and no diseases, so we feel sure that the higher purity of beets has been primarily due to our breeding work. The best measure of the gains we have made is found in the figures for the loss in molasses at all of our non-Steffen houses. The year 1938 was the first year that we were able to use a large proportion of Great Western seed, the crops of previous years being grown with foreign seed.

Molasses Produced, Percentage on Beets

Foreign seed		Great Western seed	
1933-4	4.39	193S-9-	3.S0
1934-5	4.48	1939-40	3,83
1035-6	4.21	1940-41	3.82
1936-7	4.15	1941-42	3.75
1937-S	4.10		
Average	4.27	Average	3.80

The figure obtained during the campaign just closed is the lowest on record for our company, and would have been still lower in a year with less leafspot.

We are, therefore, convinced that we have been justified in putting some emphasis on purity in our breeding program. As indicated above, the results obtained so far have been obtained mainly by attention to ash content and leafspot resistance, although the factor of harmful nitrogen has not been neglected.

Some Crossing Experiments with Sugar Beets

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The increased yields in crop plants which can be attributed to hybrid vigor is a phenomenon which must be considered by every plant breeder. In the sugar-beet *(Beta vulgaris L.)* hybrids of certain inbred lines have been reported to give yields not only greater than their parents, but also greater than the check variety R. and G. Pioneer (4).[2] As in many other cross-pollinated crops, however, inbreds of sugar beets are commonly lower in yield than their parent varieties.

Unlike corn, where large-scale controlled pollination for hybrid-seed production is possible, the sugar beet at the present time can be totally crossed only on an experimental scale, and consequently a complete utilization of hybrid vigor effects in commercial production is impossible. If natural cross-pollination between 2 strains is resorted to for hybrid-seed production, this seed will be made up of 3 types: The true hybrid, parent A, and parent B. In order that such a synthetic variety may be highly desirable in yield, it is necessary that the parents themselves be high-yielding types, and that their hybrid be exceptionally high in yield.

[1]Plant Breeder and Manager, respectively, Beet Seed Operations, American Crystal Sugar Company.

[2]Figures in parentheses refer to Literature Cited.