Research Work in Sugar Beet Breeding

H. W. DAHLBERG[1]

I believe this is one of the first occasions on which a talk on research in sugar beet breeding has been given at a general session of the Society. Recognizing that many of my listeners have been trained in other phases of the industry rather than in plant breeding, I shall make a determined effort to make my talk as understandable as possible to the average layman and business man.

In this country, as well as in all European countries, the major objective has been to develop beets which, consistent with high quality for slicing purposes, will give the maximum production of sugar per acre. This major objective must never be forgotten, and all other objectives are subsidiary to it. The industry can neither afford to use varieties which may produce high tonnage with only 14 percent sugar content, nor varieties which may reach 18 percent sugar content at the sacrifice of several tons of beets per acre.

Prior to 1920, most of the breeding work on sugar beets had been done in Europe, and while many excellent varieties had been developed, they had their shortcomings for American conditions. Thus, for example, they had no resistance to the dread curly top disease, which took a heavy toll west of the Rockies, nor to the leaf spot disease which often did serious damage east of the Rockies. The varieties were not well adapted for the long seasons and widely different climates in California, for winter growing in the Imperial valley, nor for the short seasons in Colorado, Wyoming and Montana. It has therefore been necessary for American breeders to develop entirely new and improved sugar beet varieties to meet all the varied climatic conditions in the United States and Canada.

I am sure that most of you are already familiar with the history of the development of U. S. 22 and other curly top resistant varieties by the sugar division of the Bureau of Plant Industry. It provides an important chapter in the record of American plant breeding, and I wish to pay my tribute to the men who were the leaders in this fine piece of work.

A research study now in progress, and one in which we are all engaged, is that initiated by the Savitskys for the production of single germ seed. This will be a tremendous step forward, and beet growers should begin to see its possibilities in three or four years more. It will, of course, take time to add this single germ character to our present varieties and still retain all the other important characters. Dr. Owen and his staff are doing very outstanding work along these lines right here in Salt Lake and elsewhere.

Chemical Breeding

For many years I have been particularly interested in the chemical phases of sugar beet breeding. I feel rather strongly that we will be unable to develop varieties of maximum sugar content and purity until we know more about the chemical processes that are involved in the production of sugar in the leaves by photosynthesis. In spite of volumes of research work

[1] Director of Research, Great Western Sugar Company.

done by chemists and plant physiologists, our knowledge of the actual process of sugar formation leaves much to be desired. As chemists, we know that photosynthesis is a very complex process, possibly involving as many as fifteen individual chemical reactions.

"Photosynthesis is by far the most important biochemical process on earth because it alone produces organic matter from stable inorganic materials and thus prevents life from becoming extinct. It is also the most puzzling of all biochemical reactions." (Rabinowitch)

In recent years rapid progress in understanding these reactions has been made by the use of radioactive carbon which is used as a tracer element. By the use of radioactive tracers, it has been learned that a number of organic acids are formed before sucrose is formed, and one of the important acids is glycerophosphoric acid. It is evident from the knowledge that has already been acquired that many chemical reactions and many enzymes are involved in the production of sugar. Anything which interferes with or slows up these reactions results in a lower concentration of sugar in the beet. An example of such an interfering element is an excess of nitrate which invariably results in lower sugar content.

A mechanical analogy to the production of sugar in beet leaves would be the transmission of power through a train of gears. We all know that, if one gear wheel in a series breaks down, all power transmission stops. In the same way, if one chemical component, such as an enzyme or a catalyst, fails in a chain of fifteen chemical reactions, the production of sugar will stop for a certain length of time.

In the past, it has been extremely difficult to develop sugar beet varieties of high sugar content without losing ability to produce good tonnage in the process. In other words, if one is willing to sacrifice tonnage, it is relatively easy to breed a variety of maximum sugar content.

Table 1 shows the contrast between one of our varieties with emphasis on maximum production per acre, and a European variety with emphasis only on maximum sugar content.

Table 1.—Average Results of Variety Tests at Three Locations, 1951.

Variety	Tons Per Acre	% of Mean[1]	Polarization	% of Mean[1]	Total Sugar per Acre Pounds'	% of Mean
B 530	23.71	106.2	17.25	101.8	8201	108.2
European	18.18	81.6	17.49	103.3	6374	84.3

[1] Mean of 20 Varieties.

In recent years, we have developed a new tool which makes the breeding for sugar content somewhat more certain. We have learned that high sugar content and low sodium content normally go together. In other words, a variety which can grow normally and efficiently with a minimum sodium content has a high sugar content. The sugar beet seems to have a very small physiological need for sodium salts, such as sodium chloride and sulphate. As the statisticians express it, there seems to be a high negative correlation between sugar and sodium content.

I believe you will be interested in Table *2,* which shows this relationship in various types of varieties.

Table 2.—Typical Analyses of Various Types of Beets.

	Year	% **Sugar**	% **Sodium**	**Ratio Sugar to Sodium**
Stock Beets	1950	4.8	.220	22 to 1
Swiss Chard	1951	6.3	.287	22 to 1
A-1104	1951	15.28	.036	424 to 1
5 European Varieties	1948	15.94	.066	241 to 1
G. W. 304	1948	16.52	.041	403 to 1
B 476	1950	18.68	.018	1,037 to 1
G. W. 359	1951	18.50	.021	881 to 1
B 476	1951	18.90	.014	1,350 to 1

It may be quite a few years before we will know just why high sugar content and low sodium content normally go hand in hand, but in the meantime we can still use the sodium determination as a very useful tool in breeding beets of high quality. I suspect that a rather high sodium content interferes with one or more of the enzyme reactions which are necessary for the formation of sugar in the leaves. We also know that a high nitrate content in beets interferes with the production of sucrose, and causes the beet to have a high ash content and therefore low purity. Sugar production in the beet is also inhibited by phosphorus deficiency.

In our selection work this winter, we tested more than 6,000 beets individually for sodium content by means of the flame photometer. We have already demonstrated that we can reduce the sodium content approximately one-half by one generation of careful selection.

Another phase of our chemical breeding work is the study of raffinose and other carbohydrates which we have carried on for several years. This work is described in more detail in the program of the Genetics section. Mr. R. J. Brown of our research laboratory has succeeded in developing a method whereby we can determine raffinose in individual beets, and we are working on the problem of developing a low raffinose variety. We find variations as high as 400 percent in the raffinose content of individual beets, so we feel it should be entirely possible to achieve a reduction of 25 percent to 40 percent of the normal raffinose content of our beets.

Those of you who have worked with the Steffen process know how much trouble can be caused throughout the sugar end by the presence of too much raffinose in the white and raw massecuitcs. We feel that this may be a very worthwhile phase of breeding work.

Raffinose seems to be accompanied by two other sister carbohydrates which have not yet been fully identified, and which we call carbohydrate "X." We believe carbohydrate "X" is just as objectionable as raffinose, so it is important that we learn all we can about it, and whether we can develop varieties which carry as little as possible of these two compounds. Our present varieties normally contain 0.33 percent raffinose on sucrose, and it is indicated that we have a higher concentration of carbohydrate "X" than we do of raffinose.

You may be interested to know that while there is normally only one pound of raffinose in a ton of beets, this objectionable sugar builds up *in* our Steffen process to the extent that in our company we circulate and recirculate 1,000 tons or more of raffinose through our Steffen houses and Johnstown in an average campaign. It must also be recognized that the presence of appreciable amounts of carbohydrate "X" in our juices and sirups makes many previous determinations of raffinose of questionable accuracy.

One important phase of our breeding work is that concerned with the reduction of sugar losses in storage of beets. We are attacking this problem from two angles: (1) Careful selection of beets from our best varieties which have a low rate of respiration; (2) selection of those individuals which are slow to show decay when exposed to rotting organisms such as Phoma. This work is relatively new, so we cannot yet say how rapidly we will make progress. However, we believe this phase of breeding offers considerable promise.

Development of disease resistance is, of course, one of the major objectives of any breeding program. Our company, as well as the American Crystal Sugar Company and the Holly Sugar Corporation, has developed leaf spot-resistant varieties particularly suited to our own areas. The sugar division of the Bureau of Plant Industry has developed leaf spot-resistant varieties which are used largely in Michigan, Ohio and Ontario, and curly top-resistant varieties which are used in many areas west of the Rockies. This division and some of the California companies are also making progress on varieties which are resistant to bolting and have some resistance to downy mildew.

We are also having success in breeding beets which show considerable resistance to fusarium yellows, a rather dangerous disease. We are working on the problem of developing resistance to rhizoctonia, and while this is a very complex problem, we believe we are making progress. The danger from these two diseases can be reduced by rotation of crops and improved farming, but we also think it desirable to have beet varieties which show some resistance.

We are devoting considerable effort to cold resistance studies. In this work we have three objectives: (1) To increase the length of the growing season; (2) to avoid freezeouts in the spring which often result *in* lost acreage and replanting; (3) to secure the higher sugar content which tends to go along with cold resistance. In this work we grow very large numbers of seedlings in greenhouse flats. The first step is to expose them to a conditioning or hardening temperature just above freezing. The second step is to expose them to temperatures as low as 12 degrees F. Slides which will be shown will give you a better idea of these studies. Up to this time, we have exposed some 25,000 seedlings to low temperatures.

During the next fifteen years, greater emphasis will doubtless be placed on securing many inbred lines with all the desired characters, which can be used with the male sterility character to produce hybrid varieties which will be more productive than those we have today. Such a program will involve a great deal of work, and close cooperation between the breeding divisions of the industry and of the United States Department of Agriculture. I am glad to note that this cooperation is already off to a very promising start. The work with inbred lines will involve many problems of working with large populations, of saving weak lines, of poor seed production, control of the male sterility factor, etc.

Another phase of breeding work which may demand attention in the near future is the development of polyploid varieties. A great deal of work on this subject is being done in Germany, Denmark and Sweden, and the preliminary results reported indicate that such varieties may be more productive in either sugar content or tonnage. Such varieties will doubtless be tested in this country during the next few years.

I think we are fortunate in this Society in being a young organization, even though some of us are no longer young in years. In closing my review, I wish to make this plea to the younger scientists who will carry on the research work in beet breeding for the next twenty years—above everything else, be open minded. Do not hesitate to study any tool or any theory which may lead you forward.

An outstanding cytologist, Hoskins of Wisconsin, in commenting on the long time lag in the acceptance of the chromosome theory of heredity, makes this statement, "There are commonly said to be three stages in the acceptance of an idea: (1) We don't believe it; (2) it's of little or no significance; (3) we knew it long ago. There seem to be similar stages between the first discovery and final acceptance of many scientific data."

As research men, let us not fall into any such habits of thought. Let us learn to understand and speak the language of all the scientists working in our general field, whether it be genetics, cytology, chemistry or plant physiology.