ADAPTATION OF THE SUGAR BEET TO MEET THE NEEDS OF THE SUGAR INDUSTRY IN AMERICA

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The best sugar industry in America was entirely dependent on European sources of seed for its early development. The varieties then available were developed largely by commercial concerns; and while they were the result of intensive breeding work in producing yield, intermediate and sugar types, the selection work was done in Europe. It is not surprising, therefore, that these types, or commercial brands, failed to meet the specific needs of the American grower and sugar industry.

It might be pertinent to record that except for limited cooperative breeding strain tests in this country as early as 1925, the only serious attempt by any European seed producer to meet the specific varietal problems of the American industry was initiated at Brush, Colo, in 1934 by the National Seed Co., a subsidiary of the firm of Rabbethge and Giesecke, Kleinwanzleben, Germany. While this appeared to be a well organized attempt to provide adapted and disease resistant varieties to the American grower, it came about after breeding work in the United States had become quite extensive and confidence had been established in the ability of research men in this country to meet the needs of the industry for better varieties. This project was terminated in 1938 at a time when strained international relationships were pointing towards World War No. 2.

During the first World War the American beet industry was faced with the heavy burden of providing seed for a quickly expanded acreage. Costly attempts were made to develop a domestic seed industry by the stockling or transplanting method. Seed was purchased from every available source and many fields of stock beets were unwittingly planted for sugar production, only later to be purchased by the processing company and turned back to

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the grower for livestock feed. This war-time seed emergency, coupled with
the fact that the sugar beet growers in America had been faced for years
with two major diseases, namely, curly top for the areas principally west
of the Continental Divide, and leaf spot (Gnomonia beticola) east of the
Continental Divide, focused attention on breeding for varietal improvement
and commercial seed production. The development of a self-sufficient do-

demic seed industry, largely by the overwintering method, as reviewed
by G. H. Coons (4)², provided the final control needed to induce extensive
varental improvement work in the U. S. by Federal, State, and Sugar Com-
pany research agencies. Some of the results of this improvement work will
be briefly reviewed before passing on to a discussion of the opportunities
and problems which the plant breeders are facing, particularly in connection
with the mechanization of the sugar beet crop.

It seems doubtful if the history of plant breeding has on record any
contribution to a single crop which will exceed that made as a result of
the development of varieties resistant to the curly-top disease of sugar
beets. This disease, which is caused by a virus carried by the beet leaf
hopper, Lutettia tenellus, was the principal cause of average yields (3)
as low as 1.0 and 1.4 tons, respectively, for the years 1914 and 1919 in
the California District, and 5.5 and 6.0 tons, respectively, for the years
1924 and 1926 in Southern Idaho. Such low yields, which represent losses
of from 60 to 90 per cent would eventually, no doubt, have proved fatal to
the industry in those areas subject to frequent epidemics of this disease.
The moderately resistant variety, U. S. No. 1, released to growers in 1934,
provided the first positive relief against this disease, seed being avail-
able that year for about 35,000 acres of commercial beets. Since that time,
continued improvement has been made with the further releases of U.S.D.A.
Nos. 33, 34, 12, 15, 22, 23, and 10, also Amalgamated Sugar Co. No. 600.
Some of the recognized defects in U. S. No. 1, including a strong bolting
tendency, were eliminated, while resistance to curly top and ability to pro-
2Figures in parenthesis refer to "Literature Cited"
duce were improved in the later releases. Mass selection methods have been used extensively in making these striking improvements. While real immunity to this disease appears doubtful, a high degree of resistance has been obtained, and there is every reason to believe that still better curly-top resistant varieties are in the making.

The leaf-spot disease is less ravaging in its attacks than is curly top; and for this reason, perhaps, the demand for leaf-spot resistant varieties was less urgent. This disease, caused by Cercospora beticola, may under favorable conditions result in a loss of from 25 to 40 per cent in total sugar production. Heritable resistance to leaf spot was found to exist in commercial European brands, and in Beta maritima, a closely related wild type which hybridizes readily with the commercial type, Beta Vulgare; and much progress has already been made in developing commercially acceptable varieties which are highly resistant. Two varieties (6, 7) have already been released by the U. S. D. A. to meet this problem, namely, U. S. 200 x 215, and U. S. 215 and 216, both of which represent open-pollinated hybrids or two inbred strains. In a recent release, Caskill (9) reported that U. S. 200 x 215 was compared with "synthetic check", which is a first generation increase of a mixture of 9 European brands, in a total of 83 replicated trials from 1938 to 1942 in many sugar-beet districts east of the Rocky Mountains, and that it exceeded the synthetic check by 4.7% in total sugar production as an average of all tests. Included in these tests were some where leaf spot was a limiting factor and in such cases the difference was greater in favor of U. S. 200 x 215. Over this same general area the more resistant hybrid, U. S. 215 x 216, produced 5.2% more sugar per acre than U. S. 200 x 215 in 26 replicated trials in 1941 and 4.5% more in 21 similar trials in 1942. In 40 similar tests for the same two years U. S. 215 x 216 showed an increase of 8.4% in sugar per acre over synthetic check.

Much of the breeding work of the American Crystal Sugar Company in
recent years has been directed towards the development of varieties resistant to leaf spot. Doxtator of the American Crystal Sugar Co. has provided unpublished data from four replicated trials in the Arkansas Valley, Colo., in the past two seasons which show their resistant variety, American #1, to outyield Schreiber S. S. (European) by 5.75% in root weight, 35.07% in sugar content and 34.1% in total sugar production. These results were obtained under conditions where the leaf spot epidemic was "prolonged and severe".

Breeding work by The Great Western Sugar Co., which was started in 1910 and continued extensively to date, particularly since 1925, resulted in adapted varieties which showed a progressive increase in production during the earlier generations of family selections as compared with the better European brands (1). The variety, GW59, which originated out of this long period of breeding work showed an increase of 10.8% in yield of sugar per acre over the Great Western Standard variety, GW18, for the 4-year period, 1939-42 at Longmont, Colo., and GW18 in turn exceeded the best of 4 leading European brands at the same station for the 4-year period, 1934-7, by 4.9% in total sugar production. This would indicate more than a 15% improvement over the best European variety and as such constitutes a rather outstanding example of varietal adaptation. GW18 is very susceptible to leaf spot and GW59 possesses only what might be termed tolerance to the disease. The more recent work by this Company has been directed mainly toward the development of high resistance to leaf spot in combination with other essential characters. Certain highly resistant numbers have been increased for extensive commercial use in areas where leaf spot is likely to be serious, under which conditions they are rapidly replacing the less resistant varieties.

With the many contributions to leaf-spot resistant commercial varieties it appears to be only a matter of a few years at the most until the losses from this disease will be largely eliminated. With this disease, as with curly top, real immunity seems to be doubtful. Near-immunity seems
probable, however, as observed in segregating generations of crosses between domestic numbers and certain Italian productions, and some F3 families have been observed which show uniformity for this character.

Breeding work by the Holly Sugar Corporation has been centered largely on agronomic improvement. They report "considerable improvement" in their varieties over the European checks tested.

These examples have been chosen to represent some of the more outstanding American contributions directed toward elimination of certain hazards in growing sugar beets and general improvement in the commercial varieties available to the American grower. There are others which might well be mentioned such as the development of U. S. 15, which is characterized by a desirable slow bolting tendency and is resistant to both downy mildew and curly top. Improvement in agronomic characters, particularly in shape of root and size of crown, can be claimed for many of the recent developments.

While much progress has been realized in breeding the sugar beet to meet specific American needs, the job is far from finished. If the hopes and ambitions of those who are contributing to the job are justified much improvement lies ahead in the fields of breeding for resistance to the two principal diseases, curly top and leaf spot, and in combining resistance to these two diseases into one variety, also in breeding for resistance to other diseases, particularly Fusarium yellows (2). There is some evidence which indicates improvement may be made by breeding for resistance to Rhizoctonia and damping-off in seedlings, while immunity to rust, Uromyces Betae, is clear cut in segregating generations and presumably could be incorporated into homozygous immune strains.

Resistance to cold has been shown by tests in Northern Colorado to be a heritable character, subject to improvement through selection. Plantings made in August for seed production the following year occasionally suffer severe winter injury. One or two mass selections for cold tolerance under these conditions have increased that tolerance measurably. It remains to
be determined whether this cold tolerance will also be exhibited as resistance to frost injury in the seedling, making earlier plantings and consequently longer growing seasons possible, or in the mature plant which would permit of later development in the fall.

Seed producing capacity varies greatly between commercial varieties, some of the very excellent producers of roots being rather mediocre to poor seed producers. The question of whether or not a desirable commercial variety is a good seed producer has been largely left to chance. Extensive work in this direction will, without doubt, yield positive results in increasing the efficiency of the domestic seed producers. The present rapid trend toward mechanization, which assumes the use of segmented seed, throws the spotlight on high quality seed and the plant breeder will need to turn more attention in this direction.

In breeding for higher seed producing ability extreme care must be taken to avoid undue multiplication of types which are heavy seed producers simply because they are rapid bolters, which in turn might lead to an undesirable bolting tendency in commercial fields of beets. Results obtained in tests at Riverside, California, in 1940-1 from Oct. 15 plantings were supplied by Dr. Rubanks Caraner as follows: seed of GW18 produced in Colorado showed 3% bolting on May 13, 1941, as compared with 16% and 22% for seed of the same variety grown from plantings made at Mesa, Arizona, on August 23 and October 7, 1939, respectively; also seed of U. S. 200 x 215 grown in Oregon produced 24% bolters as compared with 53% for seed of the same variety produced in Arizona. Because of this natural selection tendency commercial seed increases in Arizona are generally limited to one generation from stock seed.

In looking toward eventual mechanization of the beet crop it seems probable that the plant breeders will also be called on to provide varieties with a high degree of uniformity of root type as contrasted with the
generally heterogenous mixture of types which characterizes nearly all of
the commercial varieties being grown extensively at the present time. If
large or high crowned individuals are to be topped low enough to eliminate
the crown and leaf tissue, serious attention will need to be directed toward
individuals characterized by excessively large or high crowns. The elimina-
tion of these types. The role which the environment plays in
affecting root type will be discussed by Dr. Owen. It may be proper to ob-
serve here, however, that such characters as shape of root and the develop-
ment of undesirably heavy secondary roots, including "sprangling", will
probably continue to vary considerably with varying soil conditions re-
gardless of the extent of anticipated genetic improvement for these char-
acters.

The sugar beet industry is in a position of utilizing any improved
varieties immediately since the processor provides all seed to the sugar
beet grower. There has always been, therefore, an urge upon research to
provide those improvements which could be quickly utilized.

Much has been accomplished already in a study of fundamental prin-
ciples particularly in relation to curly top and other diseases, and the
inheritance of resistance to curly top and of other characters. Various
breeding methods are employed by different breeders, inbreeding being de-
pended upon by some while broader family and group to mass selection
methods have been employed very successfully by others. Breeding work
has been greatly stimulated and rendered increasingly productive as a
result of such improvements as overwintered seed production, photo-
thermal induction of seed stalk production in the greenhouse and planting
of seed in the southwest with later shipment of the stecklings to the
north for seed production, all of which operate to reduce a normal 2-
year program of seed production down to one generation a year. These
fundamental principles and breeding methods are working tools for the plant
breeder. Significant progress in varietal improvement has already been
made and further progress can undoubtedly be made without some of these
tools, but further intensive cytogenetic and fundamental physiologic investigations are needed to provide certain principles basic to the program.

Except for those characters already mentioned, particularly uniformity of agronomic type of root including special emphasis on small crowns, it seems doubtful if the present or post-war needs will demand much change of emphasis on the type of root which plant breeders are working for today. Single germ seeds will be most desirable if this character can be secured and incorporated into the present commercial varieties the possibilities of which will be referred to by Dr. Osen.

Breeding methodology will probably move towards more inbreeding especially if greater uniformity of type becomes an essential. Self-pollination methods are slow and subject to the obvious difficulties associated with a high degree of self-sterility, even under the most favorable conditions, loss of production for most inbreds, and lack of pollen control in making subsequent hybrids of inbred lines, but these difficulties are not insurmountable and only mean greater effort to accomplish the desired progress. Multiple-cross and backcross techniques offer possibilities for use of inbreds. It has been found true for corn in work by Jenkins (10) that inbred lines with the highest yield genotype are the descendents of foundation plants of comparably high yield genotype. Based on this principle, a method whereby open-pollinated seed harvested from highly selected individuals which were grown together in an isolated group is used to test the fundamental genetic capacity of the individual mother to produce, following which self-pollinated seed from the best-producers would be recombined immediately, offers some opportunity for breeders to make progress for several characters and at the same time to hold or increase yielding ability and to induce greater uniformity than would be possible by the broader family or mass selection methods.

It seems probable that the development of varieties which are streamlined to meet the needs of the sugar beet grower in a mechanized cultural
Immediate practice is the job ahead for those interested in varietal improvement.


10. Jenkins, Merle T.

Iowa State College Jour. Sci. 9:429-430. 1935.
