Progress With Sugar Sorgo

by E. W. BRANDES

Sorgo is grown extensively for table sirup. If it could be made to yield better, it might be used to make sugar. Sorgo is the name of convenience applied to the juiciest, sweetest-stemmed variants found in many species of the genus *Sorghum*. Between sorgo and grain sorghum, which commonly has dry, pithy stems, there are many intermediate types with few sharp distinctions in stem characters.

There is nothing new in the idea of using sorgo to make granulated sugar. All previous efforts, beginning when sorgo was first introduced about the middle of the past century, miscarried because of low yields, complicated by practical difficulties in processing the juice. Because of excessive amounts of starch and glucose in the juice, only a fraction of the sugar would crystallize. These early attempts were made before the principles of genetics were applied to plant breeding and when the conception of plant introduction and adaptation was in the “cut and try” stage, from which only now it is beginning to emerge. Although the purpose for which the plant was brought to America was not realized, sorgo became an important crop plant. During the Civil War and afterwards, it provided “long sweetenin’” in the form of thick sirup. More important, as a forage crop, sorgo occupies about 2 million acres in subhumid parts of the Great Plains.

An active revival of studies of sorgo for sugar production, based on new conceptions of plant introduction, modern plant-breeding methods, and improved sugar-processing techniques occurred in 1941, in cooperation with The South Coast Co., and the American Sugar Cane League, Inc. We cannot say yet whether the studies will lead to practical use of sorgo for sugar manufacture, but in any event the development of better varieties for sirup production, an integral part of the project that already
is on the road to accomplishment, will justify the whole effort. The general breeding program for greater yields of better quality sorgo has assurance of success, the time of reaching that objective depending upon intensity of the program. Confidence in achieving the modest objective of specialized varieties for sugar production, yielding 20-ton crops of acceptable quality, is based on scientifically sound considerations of plant adaptation and upon progress made in following them.

There is little prospect of developing a sorgo-sugar industry independently of the already established sugar crops, beets and cane. The harvesting and processing season for sorgo would be far too short to justify the required large investment in processing machinery, which for efficient operation must be elaborate and therefore expensive. Production costs would be prohibitive. The sorgo harvesting season, however, does not overlap those of beets and cane, and an off-season supply of sorgo of good quality would be a welcome addition to keep beet factories or cane mills operating longer. The advantage to farmers and processors in leveling out their labor requirements is obvious. With a longer harvesting season attained by following sorgo with sugarcane, or sugar beets with sorgo in the areas where such sequence may be found possible, all operations may be conducted more efficiently and economically.

Another advantage of growing sorgo around central factories is that it would permit more economical use of valuable byproducts, like bagasse, the mass of material that remains after the juice has been pressed out of the stalks and is used in making lumber substitutes. The comprehensive resurvey of sorgo as a source of sugar and byproducts was prompted by the ever-present need for reducing sugar-production costs.

In general, the potential dispersal areas of domesticated plants are restricted to areas not drastically different in climate from their geographic centers of origin or the points of origin of their wild prototypes. This is especially true of the plants that must rely on seed production for their perpetuation. To the more familiar climatic requirements of plants, including appropriate levels of temperature, light, and water supply during a frost-free growing season, must often be added appropriate photoperiod. Photoperiod is the relative duration of day and night, which differs at different latitudes and at different times of the year and profoundly influences the development of most plants, especially their production of flowers and seed.

Another fundamental requirement is the photothermal balance, which demands that at given temperatures there must be appropriate quotas of light. The complex, exacting, and usually interrelated requirements of plants determine where the plants will grow. Unless the plants can be made to hybridize with related plants outside of the natural dispersal area, it is extremely unlikely that the area will be materially extended. There are exceptions in the case of short-lived annuals not sensitive to
photoperiod (day-neutral forms), but in general the colonizing or re-
settlement of domesticated plants is limited by these considerations.

There is no real acclimatization of plants as the term is generally un-
derstood. What passes for acclimatization in horticulture is merely
the survival of adapted elements of heterogeneous plants in a new dis-
persal area. The environment of the new area must be compatible with
some element already present in the plant, or that can be incorporated in
the plant by crossing it with another plant. The dictionary definition
of acclimatize, “to become habituated to a foreign climate,” is mislead-
ing. But easy acceptance of that idea is the rule, fostered no doubt by
apparent exceptions like the partial compensation of altitude for latitude
and vice versa, “off-season” growing of plants in new areas, or artificially
providing requirements such as shade, irrigation, and many others.

Africa the Center of Sorgo Origin

The center of origin of domesticated sorgo is on the continent of
Africa. Satellite centers were established centuries ago in anterior Asia,
India, China, and Malaya, and more recently in southern Europe, the
Americas, Australia, and other parts of the world. The recognized wild
prototypes of domesticated sorgo (and of all cultivated sorghums) are
limited to Africa south of the Sahara, and range far down into the Tem-
perate Zone of South Africa. Sorgo is one of the domesticated plants
for which the geographic place of origin is well defined. In common with
similar, well-defined centers of origin and distribution of cultivated
plants, the situation may be likened to a target in which the greatest
number and diversity of varieties is in the bull’s-eye, and successively de-
creasing numbers are found in the concentric rings from the bull’s-eye to
the outer edge of the target. The situation is not quite so simple, because
there are secondary centers, some quite far removed from the primary
center, but essentially the situation holds true. The evidence of location
of wild prototypes and the relative concentration of diverse varieties
show that for sorgo the equatorial part of Africa is the bull’s-eye.

It is plain that the plant breeder will not be content with a meager
sampling of the forms or varieties available on part of the target, but
will try to assemble representative forms from locations on lines bisecting
the bull’s-eye and extending from the northern to the southern edges.

The first introductions of sorgo into the United States were from the
edges of the area of origin and the dispersal areas. About 1850 a variety
was obtained from an island in the mouth of the Yangtse River in China,
about 31° 30’ north of the Equator, at sea level, and 15 varieties from
Natal in South Africa, about 30° south of the Equator, at elevations up
to 4,000 feet. In mid-continental United States at latitudes 30° to 35°
north, this limited sampling of varieties from the fringes of the natural
range encountered conditions not incompatible with those of their native homes. The greatest concentration of sorgo in the United States is now precisely in that area.

Later, many races of sorghum were brought to the United States and among them were representatives of the solid-stemmed type with sugary juice. For sugar production none of the latter has proved superior to the original introductions or varieties selected from the original introductions. The significant point is that, in general, the later introductions from points closer to the center of origin in equatorial Africa grew to large size at an astonishing rate but failed to produce flowers and seed. When the imported seed was used up, these desirable forms unfortunately were lost. It is a safe assumption that among them were varieties that varied in quality of juice as well as in size and rate of growth.

We know now that the development of the inflorescence in many sorgos is powerfully influenced by photoperiod and that under our conditions the short-day forms of the Tropics must be grown farther south, or planted “off-season,” or the daily exposure to light shortened artificially in order to induce blooming. To make use of the short-day forms in breeding, it is now comparatively simple to manipulate the environment so that short-day and long-day forms will bloom simultaneously and produce hybrids.

Quite recently this has been accomplished with sugarcane, a case in which the problem was essentially similar to the sorgo problem. Long-day forms of sugarcane from the North Temperate Zone normally blooming in July-September were crossed with short-day tropical forms normally blooming (north of the Equator) in November-January by artificially advancing the blooming date of the latter. This was accomplished by growing the tropical varieties in flat cars that could be pushed into a large, light-tight photoperiod house on a daily schedule that simulated the tropical short day. Another device used successfully was to ship the pollen across the Equator by air in specially designed refrigerated containers, taking advantage of the reversed seasons. The short-day and long-day forms bloom simultaneously on opposite sides of the Equator.

In some cases, but not all, less expensive methods can be used to induce simultaneous blooming. The simple expedient of planting short-day forms in winter in the greenhouse or at subtropical stations can be used to cross them with intermediate and day-neutral forms. This device has already been used to cross tropical sorgo varieties with certain temperate-zone varieties in southern Florida. The important fact is that by new techniques an obstacle to hybridizing the numerous and important short-day sorgos with other sorgos has been removed and many desirable crosses that formerly seemed impossible now can be accomplished and valuable hybrids can be obtained.

With that background of old objectives and new techniques, a fresh
attack was begun in 1941 on the problem of improving sugar and sirup sorgos. Three lines of investigation were started: Intensive exploration for varieties in the Old World and establishing the introduced plants, as a reservoir of breeding material, at stations in the New World where they would complete a normal life cycle with production of viable seed; assembling all sorgo varieties available in the United States at a central breeding station for study and segregation of the best sugar lines; and widespread test plantings of sorgo, including tests in all important sugar-beet and sugarcane districts.

**Establishing Introduced Varieties**

The exploration for suitable breeding varieties and their importation (or reimportation) was considered the foundation of the investigation, but within a few months, while plans were being perfected, that part of the project was interrupted by the outbreak of war. It was not resumed until late 1943, but during the interim some progress was made in obtaining seed from Africa and India by correspondence. The resumption of plans for original collecting in Africa during the war was stimulated by the developing need for large quantities of industrial alcohol in the manufacture of explosives. Sorgo of available varieties had been planted around Louisiana sugar factories in 1942 for that purpose and about a quarter million gallons of alcohol were produced, but the acre yield of fermentable raw material was not up to expectations. The rapid development of higher yielding varieties adapted to the local conditions and suited to the less exacting requirements for alcohol production in contrast with sugar production was believed possible.

With the objective of obtaining seeds for the dual purpose of emergency alcohol production and long-term investigation of sugar production, the writer left Washington December 9, 1943, and arrived at Addis Ababa, Ethiopia, 5 days later.

Many other countries in Africa have well-organized departments of agriculture able to furnish information and technical assistance, but in Ethiopia the agricultural explorer is entirely on his own scientifically and must dig out independently all information and collections of plants.

The head of agricultural services in Addis Ababa gave assurance that there were indeed two kinds of mashela (sorghum) in Ethiopia, the red and the white. But the peasants of the "out back," who sometimes had to be interviewed through a chain of interpreters, knew of many different kinds and were mines of information on them. Eighty distinctly different varieties of sorghum, including two that grow wild, were obtained in Ethiopia during the winter of 1943–44.

Seed of the 80 varieties were shipped by air to Washington and distributed to five stations ranging from the Panama Canal Zone, 9° north,
to Beltsville, 37° north. At Beltsville, where they were planted in the greenhouse on March 25, the majority grew to a height of 15 to 20 feet by the end of July and produced seed heads. In contrast, the growth rate at the Meridian, Miss., station was somewhat retarded by drought. Growth rate at Canal Point, Fla., and Summit, C. Z., was about the same as that in the greenhouse at Beltsville. The average growth rate and total growth of many varieties were actually greater at these stations than in Ethiopia, but the average quality of juice was not up to that of the best quality, low-tonnage local varieties.

A succession of plantings of the latter was started on different dates in Florida in an attempt to synchronize the flowering of the local and the newly imported varieties, and it was possible to make the desired crosses with a small part of the Ethiopian varieties in the first year, 1944. The first-generation (F₁) hybrids were planted at Meridian in 1945 and were first analyzed in August and September. Although the hybrids will segregate into different forms in future generations, the F₁ results give a good index of the future breeding possibilities of a cross and the first analyses were encouraging in stalk weight and sugar content. Two progenies of the cross Straightneck M. N. × Saragie M. N. 684 gave the following results, in which the sugar content is fair and weight of stalk is two and one-half times that of the domestic parent:

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<thead>
<tr>
<th></th>
<th>Stalk weight</th>
<th>Sucrose in juice</th>
<th>Purity of juice</th>
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<tbody>
<tr>
<td></td>
<td>Pounds</td>
<td>Percent</td>
<td>Percent</td>
</tr>
<tr>
<td>Average</td>
<td>4.72</td>
<td>11.92</td>
<td>71.9</td>
</tr>
<tr>
<td>Range</td>
<td>1.75–5.80</td>
<td>9.60–13.27</td>
<td>63.3–77.4</td>
</tr>
<tr>
<td>Average</td>
<td>5.60</td>
<td>12.58</td>
<td>73.5</td>
</tr>
<tr>
<td>Range</td>
<td>5.10–6.80</td>
<td>11.07–14.35</td>
<td>68.9–80.9</td>
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The unfinished job of assembling varieties from equatorial Africa was resumed in September 1945, when Carl O. Grassl started collecting in the Sudan, and progressed through Kenya, Tanganyika, Nyasaland, Northern Rhodesia, and Uganda. With splendid cooperation from agricultural departments and other agencies that aided in original collecting and also furnished seed from their own collections, he has added more than 1,000 accessions of seed to the rapidly growing African collection established in the United States. Only a few of these appear to duplicate varieties previously collected.

Besides the personal collecting, which is always preferable and sometimes indispensable, many accessions of seed have been obtained by correspondence. By persevering effort, more than 200 packets of seed were obtained during 1942–44 from 16 countries, a gratifying testimonial to the cheerful cooperation of foreign colleagues during that time of interrupted and difficult communications. Of the number received, including many important ones, 131 came from India and the rest from countries in Africa. A possibly important source not represented in
the recent collections is that part of China extending from 110° to 120° E. in approximately the latitude of Shanghai. The Indian and Chinese sources in which we have interest correspond to ancient dispersal areas that have become secondary centers of origin of domesticated sorgos. They are important for new and more thorough investigation because of the chance that some varieties may possess one or more qualities desired in our present project and, by their location, may be assumed to be reasonably well adapted to our conditions.

Sugar Lines from Available Varieties

During the 90 years since the first group of 17 varieties were introduced from China and Africa, an immense number of variant forms were evolved by selection or by planned hybridization and by new introductions. Moreover, much confusion of names was injected in the first years by promoters who took advantage of the widespread interest in the new crop by rechristening varieties so as to enjoy temporary advantage by selling seed of "new and improved" varieties. The result was that the same variety was known by many names and they, superimposed on many legitimate new names, resulted in a formidable list. The process of coining new names, both legitimate and illegitimate, was carried on to the point where it was difficult to untangle the confused nomenclature and assay the existing material in a methodical way. No less than 389 "domestic varieties," or at least plant materials with that many designations, have been assembled at the Meridian, Miss., station.

Because of the systematic studies of competent agronomists, including C. R. Ball, and the late H. Vinall, C. V. Piper, and H. B. Cowgill, many of the more or less true-to-seed sorts in that assemblage are recognizable, but it requires a specialist to determine varieties with any degree of certainty. Every year since 1941 thousands of chemical analyses and studies of various kinds, genetic, pathological, and agronomic, have been conducted on the mass of plant material in an effort to sift out the best "sugar lines" and "sirup lines" suitable as beginning points for breeding and to continue breeding and selection with combinations already made.

Fourteen crosses of domestic varieties considered promising as sugar lines have been made. They comprise various combinations of Honey, Collier, Rex, Hodo, and White African with Cowper, Sourless, Straightneck, Hodo, S. A. 287, and Early Folger 9097. Sirup lines are represented by crosses of Hodo, S. A. 287, White African, Coleman (M), S. A. 108, and Iceberg in various combinations with C. P. Special, Early Folger 16154, Cowper, and Straightneck. All of them have now been carried to the F₉ generation. The best results have been obtained from Hodo × Early Folger 9097. More recently, exploratory crosses were

The results indicate that the only good domestic parent varieties for intercrossing are Collier, Rex, Honey, Early Folger 9097, White African, and Hodo. Combinations of these are not likely to produce high-yielding varieties for sugar production, but because Hodo is rank-growing there is a good possibility of increasing sirup yields.

Rex, Collier, and Honey were used in 1944 for more than 200 crosses with a number of the large, robust varieties obtained from Ethiopia and India. Promising parents among the latter include M. N. 414, 423, 531, 534, 543, and 684. The F2 generation was grown in 1946. Although its progenies will be actively segregated, it is probable that there will be enough material to permit selection of parents that may produce the type wanted. As indicated before, this line of breeding—crossing of the promising large tropical varieties with domestic varieties—is the main hope for success. At this stage it is only well begun.

The third main phase of the sorgo investigation, consisting of widespread indicator, or test, plantings, was started in 1942 and continued through 1945. Obviously the tests were restricted to the so-called domestic varieties because hybrids resulting from fresh importations were not available. The purpose was to get an indication of comparable expected yields especially in districts where farmers grow beets and sugar-cane commercially to determine possibilities of growing the crops in combination. A representative selection of sorgos was used, including one or more varieties known to grow reasonably well in each district. The pattern of the test and the varieties were identical in each of the districts, which were in Michigan, Minnesota, Nebraska, Utah, California, Louisiana, Mississippi, Georgia, and Florida.

The test plantings almost everywhere confirmed that the old-established varieties are not promising for sugar production, the yields per acre and quality of juice being unsatisfactory. But the plantings permitted evaluation of the different sections of the country for sorgo-sugar production. The lower latitudes and lower elevations are, generally speaking, superior for the purpose. With present varieties, and presumably with varieties improved to the extent that can be visualized, the Middle West and Intermountain areas are not suitable. The assumption is made on good grounds that the tropical hybrids now in process of development will be even more definitely restricted to the lower latitudes and elevations. In climatic and environmental requirements they will doubtless demand conditions intermediate between those suitable for the present sirup
varieties and subtropical conditions existing farther south. Prospects for the Gulf States are reasonably good. Under irrigation in the sugar-beet areas of southern California the most promising indications for sorgo-sugar production were obtained. The results of test plantings in the Imperial Valley were:

<table>
<thead>
<tr>
<th>Variety</th>
<th>Tons of stalks per acre</th>
<th>Indicated 96° sugar per acre (in pounds)</th>
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<tbody>
<tr>
<td>Straightneck</td>
<td>16.7</td>
<td>4,297</td>
</tr>
<tr>
<td>Rex</td>
<td>15.4</td>
<td>3,097</td>
</tr>
<tr>
<td>Saccaline</td>
<td>17.3</td>
<td>3,775</td>
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In this report of progress, no definite forecast can be made as to the outcome of investigations on using sorgo to make sugar. The performance of sorgo in the test cited is impressive. The prospects are brighter with the promise of better adapted varieties now in process of development. Sugar beets and sugarcane yield more sugar per acre and there is a temptation to compare harvest results directly, but it should be emphasized that in terms of sugar increment per month, sorgo even now compares favorably with the other sugar plants that require much longer crop seasons.

THE AUTHOR

E. W. Brandes was one of the organizers of the International Society of Sugar Cane Technologists in 1924, and has directed various scientific explorations in Central and South America, Asia, Africa, and the Pacific islands. At the present time he is in charge of the Division of Sugar Plant Investigations of the Bureau of Plant Industry, Soils, and Agricultural Engineering.

FOR FURTHER READING


