THE IMPROVEMENT OF SUGAR CANE BY SELECTION AND BREEDING.

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It is the purpose of this report to consider briefly the progress that has been made in the improvement of sugar cane in those countries in which this plant is grown commercially, and to establish if possible a general foundation upon which future reports may be based.

Sugar cane belongs to the natural order of grasses and is divided by Cordemoy into three species; namely, *Saccharum officinarum*, *Saccharum violaceum*, and *Saccharum sinense*. Most authorities agree that all cultivated canes are derived from the first species named. The second one is found in Hawaii, while the third is the Chinese cane. At each joint and underneath the leaf is the bud or eye, which was thought for many years to be the only means by which cane could be propagated and which is still the principal means of propagating this plant commercially. This bud is about the size of a pea or a little larger, and varies in size and shape on different canes. The head of the cane, commonly called the arrow, consists of large white or gray clusters of flowers, a panicle of soft silky spikelets carried on an elongated peduncle. The spikelets are made up of three scale leaves, two exterior and one interior. The two outer ones are called the glumes and the interior one the palea. Within this covering is the flower, consisting of three stamens and one pistil. The ovary is ovoid and sessile, and contains only one ovule. It carries two styles of a reddish color, which in turn carry a large number of stigmas. The time of flowering varies from eight to fifteen months, but the cane is not fully ripe until from two to three months after flowering.

The composition of sugar cane varies with the species and with the conditions of growth. The limits of composition of cane as given by Dr. Deerr in his work on Sugar and Sugar Cane is as follows:

	Per cent.
Water	69 to 75
Sugar	10 to 18
Glucose	0 to 2
Fiber	8 to 16
Ash	3.10 to 8.10
Organic non-sugar	$\frac{1}{2}$ to 1

What is here called fiber refers to the insoluble matter and not alone to true cellulose.

One of the strongest incentives to the improvement of the quality of sugar cane has been the development of its rival as a sugar plant—the sugar beet. It is therefore only within comparatively recent years that earnest systematic efforts have been made to improve cane as a sugar-producing plant.

Two general methods have been employed in improving the size,

quality and habits of sugar cane. One method may be designated as vegetative or bud selection, and the other as breeding. The former undoubtedly has been carried on by cane growers either consciously or unconsciously from the time this plant was found to be of economic value, even without having in mind a definite type of cane to be produced. Vegetative selection is based upon bud variation, in which peculiar or desirable characters have been recognized by the grower; as for example, size of cane, color, ability to stand erect, size of nodes, length of internodes, ability to ratoon, etc. Some effort has been made to improve cane by chemical selection, and, while considerable progress has undoubtedly been made along this line, it has been largely because the desirable internal qualities of cane correspond to some extent with the desirable external qualities. The difficulties in the way of chemical selection under the vegetative plan of breeding are similar to those of other plants. The soil and climatic conditions, as well as methods of cultivation, cause considerable variation in the sugar content of the cane. As an instance of the variation in sugar content due to external conditions it is stated that the crop in Demerara in 1900 consisted of one variety only. The canes grown on virgin soil contained less than eleven per cent sugar while the same variety growing on older land produced fourteen per cent or more. This fact has been observed repeatedly in connection with sugar beets, and it is undoubtedly a general rule that the composition of the plant varies within wide limits depending upon soil and climatic conditions. Likewise the part of the cane tested as well as the age of the cane causes variation in the results obtained. The lower part of the cane for example contains considerably more sugar and less glucose than the upper part. The following data from a table prepared by Bonane establishes this fact.

A. Plant imperfectly ripe and still in full vegetation. The lower part contained 13.74 per cent of sugar and 1.78 per cent of glucose; the middle part contained 14.11 per cent of sugar and 2.44 per cent of glucose; the upper part contained .85 per cent of sugar and 4.11 per cent of glucose; and the white top contained 4.01 per cent of sugar and 6.57 per cent of glucose.

F. Plant very ripe, 14 months old. The lowest fourth contained 22.68 per cent of sugar and .51 per cent of glucose. The lower middle fourth contained 22.68 per cent of sugar and .52 per cent of glucose; the upper middle fourth contained 22.68 per cent of sugar and .52 per cent of glucose; the upper fourth contained 22.03 per cent of sugar and .53 per cent of glucose; and the white top contained 16.84 per cent of sugar and .70 per cent of glucose.

The other plants used by Bonane were mostly ratoons, which showed a marked decrease in the sugar from the base upwards and a corresponding increase in glucose. It is important therefore in comparing canes for the purpose of establishing a higher sugar content that the sample be taken from the same part of each cane tested. It has been ascertained that over-ripe canes rapidly deteriorate, hence the exact time of making the test is important. Inasmuch as different varieties of cane ripen at different ages, it is difficult to make tests that

are comparable, and especially is this true since the latter ripening variety may be subjected to weather conditions during the ripening period that are entirely different from the weather conditions that obtained while the earlier varieties were ripening. It is also true that the buds on the lower nodes of the cane are less active than those at the upper nodes. For these reasons it is customary in some localities to use the upper three or four nodes for planting, while the lower part of the cane is used for sugar production. Whether or not the practice of using buds from that part of the cane poorest in sugar and richest in glucose will not eventually cause the canes to deteriorate can not be determined from any of the reports examined. The fact that the buds are practically independent of the canes so far as germination and growth are concerned would lead to the conclusion that the quality of the cane produced from the bud would be but slightly influenced by the quality of the cane upon which the bud was borne. This can be determined with certainty only upon investigation.

The improvement of cane by seminal breeding has been confined to the past two decades. For many years it was supposed that the seed of cane was infertile. Although we find some references to the production of seedling canes in India, no importance was attached to these statements by cane producers. Darwin, in his work on the variation of animals and plants under domestication, cites cane as one of the plants which does not produce seed. He bases this statement upon the record of various observers in the principal sugar countries of the world. De Candolle in his *Origin of Cultivated Plants* states that the seed of cane has never been described nor figured. For the reason stated, the buds on the joints of cane were considered the seeds of this plant and were, as already stated, looked upon as the only means of reproduction. In 1858 it was found by J. W. Parris, of Barbados, and in 1860 and 1861 by F. B. Carter, of that Island, that a few of the seeds produced by sugar cane were fertile, but they were so few in number and the difficulties that arose in trying to produce canes from seeds were so great that the idea was abandoned. It seemed to be the purpose of those who discovered fertile seeds in early days to do something in the way of producing commercial cane from seeds, while very little attention seems to have been given to the production of improved strains or varieties at that time by seminal variation. In 1887 fertile seeds of sugar cane were again discovered almost simultaneously by Professor Soltwedel, Director of the Samarang Station in Java, and by Mr. J. B. Harrison, Island Professor of Chemistry and Agricultural Science at Barbados, in conjunction with Mr. T. R. Bovell, Superintendent of Dodd's Reformatory. The flowers of cane were figured by Professor Soltwedel probably for the first time, and it is claimed by some writers that his discovery of fertile seed and the production of seedling canes therefrom slightly antedates the discovery of Messrs. Harrison and Bovell. The two investigators last mentioned, however, made the most practical use of this discovery, or rather rediscovery of fertile seeds of cane. The method of their discovery is briefly as follows: The canes were planted in thirty-six

plats of eighteen varieties, so arranged that two sets of each kind were planted side by side. The plats were noticeable for the number of arrows sent up by some of the varieties. Mr. Harrison gave strict orders to the laborers to call his attention to any peculiar or unusual grasses that appeared among the canes during the season. Accordingly his attention was called to a few tufts of grass toward the end of January. He states in his report that a great deal of difficulty was experienced in keeping these plants alive as the quickly shriveled under the influence of the sun's rays. However, by keeping them shaded and constantly watered he succeeded in saving upwards of sixty of the plants. This probably is the beginning of the breeding of sugar cane, at least so far as we have any record of this phenomenon.

In 1887 Dr. Soltwedel tried to cross one of the cultivated varieties with one of the wild kinds. It was not possible to ascertain whether or not the cross fertilization was successful. Fertilization was observed in twenty varieties of cane other than the variety used, and fertile seed was produced in eleven of these varieties. The number of seeds produced varied from thirty-one per cent to less than $\frac{1}{4}$ of one per cent. A very large number of Dr. Soltwedel's seedlings perished. In fact he obtained strong seedlings from only one variety, the Yellow Hawaii. These attained a height of $2\frac{1}{2}$ meters. The fact that Dr. Soltwedel and Messrs. Harrison and Bovell worked independently upon this interesting problem and obtained practically identical results would lead us to the conclusion that both parties are entitled to great credit for this discovery, which undoubtedly means much for the future of the cane industry.

The principal difficulties in the way of the improvement of sugar cane either by vegetative selection or breeding are due to several general conditions, such as confusion of names, non-stability of characters, and size and position of flowers. The confusion of names of existing varieties is due in part to our lack of knowledge of the origin of cane and in part to the tendency on the part of planters to give old varieties new names when they are introduced into new localities. Some writers claim that the original home of the cane is China; others find strong evidence that it originated in India, while still others claim that it is a native of the Pacific Islands. Without the original type plant we are unable to determine what are variations and what are true characters. Again a cane introduced into Louisiana from Hawaii, for example, may receive in Louisiana the name of the planter who first grew it. If taken to Queensland, it may receive still another name, all of which tends toward great confusion in regard to the true name and to the number of existing varieties.

As has already been indicated, it is difficult to fix upon any characters which may be sufficiently stable to establish a basis for varieties. Among the important points toward which cane breeders aim may be mentioned the following: (1) Good yield. (2) High sugar content. (3) Upright growth. (4) High fertility. (5) Freedom from disease. (6) Fair fiber in megass. (7) High percentage of juice. (8) Early maturity. (9) Ease of crushing. (10) Easy clarifica-

tion of juice. (11) Flinty rind. (12) Satisfactory ratooning. These characters may all be summed up in the one statement that the cane most desired is the one that will yield the largest quantity of sugar per acre with the greatest certainty and with the least expense. The value of nearly all these characters is self-evident. It is of prime importance that a good yield of cane rich in sugar be produced. A tendency in the cane to fall down produces not only crooked canes that are hard to handle, but canes that are low in sugar and rich in glucose. The fiber in the megass is of special importance in those localities where this material is used as fuel.

One of the most common characters which has been used to distinguish varieties is that of color. To this have been added size of nodes, length of internodes, general character of arrows, and habit of growth. In regard to color as a varietal distinction, Professor Stubbs in his work on the cultivation of sugar cane divides all the varieties found in Louisiana into three classes according to color. In the first class he places all white, green and yellow canes; in the second class, all the striped canes; and in the third class, canes having solid colors other than in class one. He then divides the canes under the varietal classes into groups, the number of canes in each group varying from one to nine. All the members of the same group are, according to Professor Stubbs, identical. Whether or not canes retain their color under the various soil and climatic conditions in Louisiana, Professor Stubbs does not state, but according to Professor Eckart color is not a staple character, at least with some varieties. He has made a study of a large number of varieties, and states that between White Bamboo and Yellow Caledonia there seems to be no difference and after four years trial it is impossible to distinguish one from the other. This arrangement by Professor Stubbs is made for the purpose of bringing order out of chaos regarding the names of the varieties of cane. Several years ago the Louisiana Station inaugurated a plan whereby the different varieties of cane grown in various countries could be exchanged and compared for the purpose of determining which are identical. This will undoubtedly do much toward solving the problem of varieties, providing the influence of soil and climate has not already produced marked changes in the imported varieties so that they can no longer be recognized as belonging to the type from which they originated.

In conclusion it may be said that much has been accomplished in improving sugar cane in spite of the many difficulties and discouragements that attend the selection and breeding of this important plant. Not only has the yield of sugar per acre been greatly increased, both by increased yield of cane and by a higher sugar content, but varieties more or less resistant to disease have been produced, thus making the crop more profitable and more certain. Furthermore, varieties suited to different soil and climatic conditions have in some instances been developed in this manner, greatly increasing the acreage. That much may still be done to improve the quality of sugar cane and the quantity that may be produced per acre is certain, but it will take years of

patient painstaking work to approach the desired goal. In our own country much has been accomplished by the Louisiana Experiment Station. It has not been possible in this country to produce canes from home grown seed owing to the fact that cane grown in this country does not produce fertile seeds. Imported seeds have produced canes some of which are very promising along several lines of improvement. In Java a great deal has been accomplished in producing canes immune to disease as well as in producing improvements along other lines. Likewise in Australia, Hawaii, and other sugar-producing countries, the methods of improving sugar cane have been inaugurated along right lines, and the future is full of promise for good results. The most satisfactory results have been attained in the British West Indies, where improvement by seminal variation was first successfully started and where it has been carried on continuously for nearly twenty years. While the vast majority of seedlings produced have been rejected for good reasons, a few have been more or less satisfactory, and are now being grown in nearly all cane-growing countries of the world. The methods of selecting and hybridizing are fully described in Professor Stockdale's report of last year.

Mr. C. G. Williams, of the Ohio Experiment Station at Wooster, presented the following paper:

CORN BREEDING AND REGISTRATION.

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The basis upon which corn breeding and registration rests is the ear-row test. This test, when wisely and carefully conducted, is a very satisfactory method of determining the comparative yielding ability of ears of corn. In making one's selection of ears for this test it is probable that some time and labor may be saved, i. e. some ears of little value be kept out of the test, if the selections are made as the corn is ripening in the field.

Good ears of corn are what they are as a result of either heredity or environment. Selected apart from the growing plant, the chances for choosing ears, which owe their excellence to heredity, are not the best. Most especially productive plants owe their superiority to immediate environment. Extra food, sunlight, and moisture, resulting from the thin stands, are responsible for many more large ears of corn than is heredity. When selections are confined to the best plants and ears obtainable, which have been grown under normal environment, a pronounced step is taken in the direction of sifting out the temporarily and accidentally good from the inheritably good. "Natural selection," De Vries tells us, "is a sieve." So is all selection.