THE BREEDING OF SUGARCANE

By N. L. Dutt, F.A.Sc.

(Director, Sugarcane Breeding Institute, Coimbatore)

I. Introduction

The main scientific problems which fall within the purview of the Sugarcane Breeding Institute, Coimbatore, are those connected with the breeding of improved varieties and thus relate chiefly to the raw material of the Sugar Industry, *viz.*, the sugarcane supplied to the factories. The sugar industry in India stands on a somewhat different footing as compared to other industries, as the bulk of the cost of the finished product, *viz.*, sugar, is represented by the price paid for the raw material which is nearly $\frac{2}{3}$ of the cost of production of cane sugar. As such, the protection which was granted to the sugar industry was one of protecting a particular branch of agriculture until such time as improvements in methods of cultivation and developments in research enable the agriculturist to increase his yield per acre while maintaining or increasing his profits.

The crux of the problem is, therefore, raw material, not merely because of the high proportion of its cost in the total cost of cane sugar, but principally because the quality and the output or yield per acre of the raw material were very poor, indeed, the poorest in the world. The yield of cane in the sub-tropical North India (which represents 80% of the total acreage under cane in India) was only 10 tons per acre against 70 tons in Hawaii, 60 tons in Java and 30 tons in Cuba. This yield has, with the spread of improved varieties of cane bred at Coimbatore, risen by 50%, but there is still a long road to travel if we are to compete on equal terms with other sugar producing countries and place our sugar industry on a sound basis. It is true that in Cane Competitions yields of over 60 tons per acre have been recorded in Uttar Pradesh and elsewhere in North India and over 100 tons per acre in the Deccan Canal Area of the Bombay State, but what is to be aimed at is high or at least fairly satisfactory average yield of cane over the main cane-growing areas. The potentiality of high yields of Co. canes in cultivation has thus been demonstrated by the high yields in Cane Competitions and the aim of satisfactory yield by the average cane-grower can be achieved by proper cane development. Cane Development Departments have now been set up in the chief sugarcane growing States and the Indian Central Sugarcane Committee has also sanctioned long term Cane Development Schemes, and progress in this behalf may now be hoped for.

In the present note only the technical or scientific problems are briefly touched upon. These problems are varied and of a complicated nature.

II. CANE-BREEDING PROBLEMS

The very first problem which the Institute had to tackle was whether the varieties that had to be crossed would flower under Coimbatore conditions and set seed satisfactorily. So far as the technique of crossing and raising of seedlings is concerned a satisfactory technique was evolved and is in vogue for the last four decades with slight modifications depending upon the combinations that have to be effected each year but the problem of flowering still remains. Quite a few varieties have not yet become available for hybridisation because they have not flowered so far while others are unavailable for effecting certain desirable combinations as the disparity in the time of flowering is such that they cannot be mated. A scheme on Sugarcane Physiology has now been in existence for the past few years devoted mainly to the study of the physiology of flowering in sugarcane and some details of the progress made in this direction are given in a later paragraph.

The second problem was whether the canes bred at Coimbatore will suit the rather rigorous climatic conditions of the sub-tropical North Indian regions where the bulk of the area is situated. To ensure the success of Co. canes in North India, Dr. Barber and Dr. Venkatraman took the unusual step of utilising the wild *S. spontaneum* in breeding and this paid rich dividends as the very first seedling of a direct cross between *S. officinarum* and *S. spontaneum*, *viz.*, Co. 205, was an immediate success in the Punjab. Only the Coimbatore form of *Saccharum spontaneum* and later Glagah, the Java form have been used at Coimbatore. A few seedlings have been raised from Burma spontaneum also. But there is such a wealth of *S. spontaneum* forms in India that this Institute has now organised an exploration for collecting the wild forms of *Saccharum* and allied genera from all parts of the Indian Union in its Spontaneum Expedition Scheme. An account of this important work is given in a subsequent section.

Another problem of some importance which presented itself was that no very satisfactory method was available for assessing the male viability. Attempts at germination of sugarcane pollen *in vitro* had failed and the storage of pollen in a viable condition was attended with its own difficulties. Ultimately a method for successfully culturing sugarcane pollen was evolved, but the storage of pollen is conditioned by the fact that howsoever well stored, like certain other graminaceous pollen, it does not retain its fertilizing capacity beyond 48 hours. On the pistil parent side, tests on the stigma receptivity were made and the time taken in fertilization determined.

The problem of evolving canes suitable for local areas in the various States is a perennial problem because for one reason or another varieties go out of cultivation; moreover better varieties are bred and come to replace the older ones from time to time. The breeding of better and yet better varieties is thus a continuous process. In the Punjab tract in North India Co. 205 gave place to Co. 285. The cane which proved to be almost an universal cane for the sub-tropical belt was Co. 213 and was in cultivation from East Punjab to West Bengal, and formed the backbone of the sugar industry for a number of years. It, however, fell a prey to red rot disease and had to be replaced by other varieties. Co. 312 and Co. 313 then came into the picture, but Co. 312 has also shown susceptibility to red rot and needs replacing. There has been during relatively recent years a reorientation in the type of canes for North India. It was felt that slightly thicker or medium thick canes could with advantage be cultivated in North India provided they could withstand the extremes of temperature. The advantage would be that with better cultivation and irrigation they could give much higher yields which would have been impossible with the thinner reed like older varieties. Special combinations were therefore devised and in due course canes like Co. 421 and Co. 453 which are somewhat on the thicker side as compared to Co. 213 and Co. 285 have come to occupy fairly extensive areas in North India. This process is being continued and the search for new parents from among the Co. canes themselves most of which are tri-species hybrids continues each year as more experience is gained.

The breeding of suitable varieties for the tropical States of Bombay and Madras was taken up at a relatively later stage as compared with the canes for North India and fortunately in Co. 419 an almost universal cane for the tropical conditions in Bombay, Madras, Hyderabad, Mysore and Orissa was evolved and shows very good growth and yield. Other recent canes are Co. 449 and Co. 467. Naturally the parents employed for breeding canes for peninsular India are very different from those employed for breeding canes for North India as in the canes for the South a preponderance of *S. officinarum* can with advantage be woven into the parentage. Care, however, is taken that a certain amount of hardiness is also introduced.

The interesting work on the intergeneric hybrids including the sugarcane × bamboo hybrids is now reserved more for academic studies in the Cyto-genetical Section excepting crosses with *Sorghum* for evolving early canes and those with *Sclerostachya* and *Narenga* for disease resistance.

Breeding for earliness and high sugar is an aspect which concerns the sugar factory most. High sucrose and earliness in ripening have been found

difficult to combine with satisfactory yield. However, Co. 313 among the earlier canes and Co. 527 among the relatively later series have fulfilled the requirements to some extent. Among the recent canes Co. 630, Co. 644, Co. 659 and Co. 686 combine in themselves early maturity and fairly high tonnage, but these are as yet in the experimental stage. In connexion with the selection of early ripening varieties studies on the anatomy of cane leaves have indicated correlation between cell size of leaf and maturity. The size of the stomata in both lower and upper epidermes and the bulliform cells in the upper epidermis have been noticed to be smaller in the early ripening varieties as compared to the late maturing canes.

Recently the formulation of breeding aims for production of varieties with certain specialised characters has become more necessary with the continually changing outlook both from the agricultural and factory points of view. Attention is now being paid to the production of (1) canes which do not have pith and are not hollow, (2) chewing varieties, (3) disease-resistant varieties, and (4) varieties with good manufacturing qualities. After an elaborate study of the varieties combinations have been devised which produce canes that show no tendency to pith formation or hollowness in the centre. The pithy portion does not contain juice and pithy stalks are less in weight. One other drawback with stalks having pith is that the canes tend to dry up quicker after harvest as also in the field when kept on in hot weather. There has been a demand for chewing canes both in urban and rural areas. This in some respects has been difficult of achievement for chewing qualities and the yield particularly under North Indian conditions are hard to combine. Canes like Co. 798, however, have been recently released for trial and may succeed at least in some tracts.

Attention is also being devoted to the production of varieties resistant to red rot. This aspect deserves serious attention since some of the commercial varieties are falling a prey to this disease. In the work on breeding of disease-resistant varieties with particular reference to red rot, crosses between highly susceptible varieties and those which are moderately susceptible have shown a great deal of variability in the matter of disease resistance and the data available indicate the need for caution. It is now felt that the best method of evolving red rot resistant canes would be to inoculate the seedlings and study them for red rot resistance and release only those which are found to resist the disease.

As regards the manufacturing qualities, a beginning has been made in the study of the chemical composition of the juice as it affects the quality of (1) gur as manufactured by the average cane grower and (2) white sugar

in factories. The prominent Co. canes in cultivation have been analysed for total nitrogen, protein nitrogen, ash and colloids. The various constituents of the ash, *viz.*, lime, phosphoric acid, sulphate and iron were also determined. It is proposed to continue this study to seedlings of known parents to see how far they contribute good and bad juice characters to their progenies.

III. Cyto-genetical Problems

A Cyto-genetical Section is an essential limb of any plant-breeding project. Studies on cyto-genetics of sugarcane have been conducted at Coimbatore by Drs. Janaki Ammal and N. Parthasarathy and now by Dr. Raghavan. The studies have revealed that cyto-genetically even the simplest of sugarcane material is highly polyploid with an equally high degree of genetical impurity. To this extent in sugarcane breeding there must always be a very large element of chance.

The main problem is to bring sugarcane breeding in a line with other crops which are within the operation of mendelian heredity. This can be achieved by simplification which in its turn may be expected to re-establish a fairly high degree of purity. One way of achieving this is through haploid parthenogenesis of which no sign exists so far. Another is by continued back crossing with forms which are likely to be the progenitors of sugarcane. This is also being done. But the problem is to bring about an elimination of all chromosomes other than those of officinarum basic complement. Study of the meiotic configuration in such back-crossed progeny has thrown light on the constitution of *S. officinarum*. There has also been found recently chromosome eliminations *en bloc* and this makes it possible for different chromosomal races to come into existence and it is suspected that this phenomenon also plays a very important part in sugarcane breeding. Cytoplasmic inheritance has also been noticed and it is presumed that in sugarcane breeding more importance has to be paid to the mother than to the staminate parent.

IV. Spontaneum Expedition Scheme

Shri R. R. Panje is in charge of the Spontaneum Expedition Scheme. The strenuous work of the actual exploration is now drawing to a close and the study of the botanical and agronomical characteristics of the over 200 forms as also of the exotic types imported from South-East Asia, the Middle-East and the African areas has been taken up.

On a very close study of the characters depends the utilisation of these forms in breeding work. The special value of the wild sugarcane lies in

the fact that apart from at least two sub-species, *Saccharum spontaneum* has several ecological races which are adapted to a variety of habitats, and these ecotypes are to some extent associated with a fairly wide range of chromosome numbers. Among the forms collected are giant types, thicker and broader-leaved than some of the cultivated canes; dwarf, bushy types; spreading types; rhizomic forms and types with certain unusual morphological characters. Observations on the distribution and the ecological adaptations of these forms in the original habitats against the behaviour of the trans-plants have given indications of the extent of utility of the forms in breeding. Selections of genetic stocks have been made from out of a wide range of useful characters, *viz.*, habit, growth-vigour, drought-resistance disease-resistance, tolerance to salt, sugar content, etc. Some of the selected forms are being tested for the heritability of the desirable characters. Work on vegetative and floral morphology, starch content, epidermal patterns and chromosome numbers has shown certain interesting trends within the species, though the complete picture will take yet some time to emerge.

The taxonomy of *Saccharum* and the allied genera needs a close scrutiny. The delimination of this genus from the allied genera has undergone changes and the question of the validity of certain genera is awaiting further research. A beginning towards this has been now made through studies on the morphology, anatomy, ecology and distribution, as also on the cytology and biochemistry of the forms and species within *Saccharum*. These aspects together with the botanical and agro-physiological assessment, the pre-testing of the genetic stocks and the building up of presumptive parents out of the wild material constitute by themselves a whole branch of research bearing on sugarcane breeding with a far-reaching applicable value.

V. SUGARCANE PHYSIOLOGY SCHEME

Studies on the physiology of flowering in sugarcane have been conducted at Coimbatore by Mr. N. D. Yusuf and now by the present Sugarcane Physiologist, Dr. M. V. Saradhy, and his Senior Assistant, Mr. R. Narasimhan. There is a lack of precise knowledge of the factors controlling development in the cane plant. Identical response to treatments which are unrelated or even opposite in nature and variance in the effect of the same treatment during different years have been noticed. For instance, the usually non-flowering *S. spontaneum* Burma, recorded favourable response to the 22 hours darkness treatment while later it gave favourable response to 22 hours continuous light treatment. As regards variance in results, early flowering was induced in a previous year, in POJ. 2725 in the 6 hours-day treatment, while in later experiments the same treatment delayed the flowering.

The experiments have now been graded at closer intervals. Photoperiods ranging from ¾ hour to 12 hours both in respect of extra light and darkness and in relation to (1) pre-initiation, (2) initiation, and (3) post-initiation stages of the floral primordia are in progress for the last two years. Sugarcane seems to be very sensitive or exacting in its photoperiod factor. In the pre-initiation stage any deviation of over 1 hour completely inhibits flowering. At the initiation stage the flowering is delayed while in the post-initiation stage there is not much effect. As regards the irrigation and manure factors, profuse irrigation seems to have an accelerating effect on flowering while the nitrogenous and phosphatic manures at the levels (100 lb. Nitrogen, 75 lb. P_2O_5) tried did not have much effect. These experiments are proposed to be continued with graded and increasing manurial doses.

As a pre-requisite to further studies on flowering, observations on the initiation and growth of the sugarcane inflorescence have been made. It has been found that the floral initiation takes place by about the end of August each year and is practically simultaneous in both early and late varieties. Though, as now found, the floral initiation is at about the same time, the factors which make a variety to flower early and another late in the season have yet to be determined. Observations on the growth of the inflorescence indicate that the inflorescence completes its growth in length at the short blade stage and the emergence of the arrow is the function of the elongation of the stalk. The growth of the inflorescence itself appears to be of the auto-catalytic type while the elongation of the stalk is exponential. Negative correlation seems to exist between the elongation of the inflorescence and stalk.

VI. Survey of Manufacturing Qualities

Shri K. V. Gopala Aiyar is in charge of the Chemistry Section and in addition to the rather routine work of analysing the juices of the very large number of sugarcane seedlings under test each year, has recorded valuable observations on the effect of soil conditions on the growth and quality of cane varieties as also the effect of planting in different months of the year on the maturity and growth of sugarcane. He is now conducting for the last four years a survey of the factory areas with a view to gathering information on the manufacturing qualities of the Co. canes in cultivation. This information when completed is proposed to be utilised in selecting suitable parents in the breeding programme so that parents which pass on to their progeny undesirable qualities in the juice may be dropped from the list of parents and only such as possess good qualities retained for crossing work.

There has been considerable improvement in the recovery of sugar per cent. cane obtained by the sugar factories in India in recent years. Side by side with this increase there is also a steady increase in the sucrose per cent. in the cane crushed, while the fibre has remained more or less at 15·50%. It may be said that the improvement in recovery is partly on account of the rise in the technical efficiency of factories and chiefly on account of the improvement in the quality of the Co. canes.

Juices of some varieties have on certain occasions been found to be refractory. In Bombay State difficulty was experienced by some of the factories regarding clarification of juice in POJ. 2878. It was associated with phosphate deficiency in some cases, though not always explained on that score. In Bihar, difficulty was encountered in filtration with the juice of Co. 313. The practice during the recent years has been to study as far as possible the seedlings in the test plots at Coimbatore before they are released to the State Testing Stations for the non-sugars in juice including colloids, ash, phosphoric acid, as also protein and non-protein nitrogen as these are the constituents which will affect the manufacturing qualities.

The non-sugars may well be expected to assume greater importance in the relatively inefficient open pan system of gur manufacture which is a cottage industry consuming more than 60% of the crop. Large varietal differences in gur quality have been noticed and the following juice characteristics would appear to be conducive to good quality gur; (1) a low level of colloidal matter (total colloids and also gums and pectin), (2) a low level of mineral matter, (3) a higher level of phosphates, (4) a smaller proportion of mineral matter present in the colloidal stage, (5) lower values of soluble SiO_2, Fe_2O_3, Al_2O_3 and CaO, and (6) a low level of non-protein nitrogen.