METHODS IN SUGARCANE BREEDING

J. Thuljaram RAO *

Historical

The cultivation of sugarcane is known to be ages old and can be traced to civilised races in India and China. The improvement of the crop is as old as the cultivation of the crop itself in the sense that forms with better sweetness and less fibre fit for chewing purposes have been consciously selected by man from among the diverse forms available under natural conditions. We know the white sugar industry is but of recent origin. The planting of sugarcane through the vegetative buds at the nodes of the stalk made it easier for keeping the genetic purity of the material unless mutation occurred in nature which is very rare.

History tells us that two distinct classes of varieties were in cultivation in the sugarcane growing areas of the world before any breeding work was thought of in sugarcane. The clones of the tropical regions of the world had thick barrels in various flamboyant colours and stripes with good juice quality and moderate fibre content. Sensitivity to moisture stress, adverse climatic conditions and pests and diseases were characteristics of the clones which together were classified under the specific name *Saccharum officinarum.* In contrast were the thin hardy varieties, low in sugar and high in fibre with extreme tolerance to adverse soil and climatic factors and certain pests and diseases. These were being grown in North India and China and were classified as the thin canes. These have now been classified under two species *S. barberi* and *S. sinense.* Thus the cultivated sugarcane consists of the above three species. While the clones of *S. barberi* and *S. sinense* are no longer commercially cultivated in any part of the world now, certain clones of *S. officinarum* are still in commercial cultivation for chewing purposes, particularly in India, Pakistan and Bangla Desh. But continued interest in these three species still persists since these form the ancestors for all the improved hybrid varieties in cultivation today in the world and many of them are still to be utilised in the breeding programme. These clones are maintained as part of the World Germ Plasm Collection at Canal Point Sugarcane Station in U.S.A. and Sugarcane Breeding Institute, Coimbatore, India.

Two wild species of *Saccharum* genus have been recognised - *S. spontaneum* and *S. robustum.* The former is a polymorphic, polyploid species found in a wild state throughout the old world with forms varying considerably in morphology and chromosome numbers and possessing tolerance to adverse conditions and resistance to certain pests and diseases of the crop. *S. rubustum,* again a polyploid species occurring wild in the Pacific islands, particularly New Guinea, New Caledonia, etc. has been discovered recently.

Origin of saccharum species

Considerable interest and work has gone into the aspect of the origin of the *Saccharum* species with a view to utilise this knowledge in the breeding programme leading to higher yields, better levels of sugar content and resistance to adverse soil and climatic conditions and diseases and pests. Parthasarathy (1946) suggested the origin of *S. barberi* through promiscuous hybridisation between *S. officinarum* and *S. spontaneum* in the region of Bihar and Orissa in India. This hypothesis has received support from the studies of Daniels and Daniels (1975) who have produced evidence to show that "*S. officinarum* was known in India and China in the early centuries B. C. and was available for Introgression." The origin of *S. sinense* as a result of introgression between *S. officinarum* and a tetraploid *Miscanthus* in the China -

* Director, Sugarcane Breeding Institute, Coimbatore - 641007, Tamil Nadu, India

Japan area has been suggested by Grassl (1964). Daniels and Daniels (*loc. cit*) have suggested the possibility of *S. sinense* having evolved in Assam and eliminated from the area due to redrot disease. China can be a place of diversity of the species.

Daniels and Daniels (*loc. cit*) suggest India as the centre of origin of *S. officinarum* with the centre of diversity in New Guinea. The origin in India would be the Indo-Burma-China border which needs intensive exploration. The suggestion is made by the authors that though *S. officinarum* originated in North India, it could not survive due to the redrot disease and found in New Guinea the ideal climate and absence of the disease for diversification into a large number of clones collected there through expeditions. According to them "the evidence for the origin of *S. officinarum* in India versus Irian-Jaya-Papua-New Guinea" is strong.

As regards the origin of the genus *Saccharum*, Daniels, Smith and Paton (1975) state "we propose the alternate hypothesis (alternate to New Guinea generally accepted as the centre of origin of sugarcane) that introgression between *Ripidium*, *Sclerostachya* and *Miscanthus* at varying levels of ploidy in various geographical locations in India may have produced the sugarcanes *S. officinarum*, *S. barberi* and *S. sinense*. *S. officinarum* was the most efficient product derived from a particularly favourable combination."

Sugarcane as breeding material

Since early times, the ignorance of man that sugarcane can produce fertile seed led to the continuous propagation of the crop through vegetative means. However the occurrence of a large number of diverse forms in native gardens in New Guinea is evidence that natural hybridisations must have taken place and human interference has resulted in the selection of sweeter and less fibrous clones meant for chewing which was the only objective in those days.

The simultaneous discovery in 1888 in Java and Barbados that sugarcane can produce fertile seed and seedlings can be raised from the seed led to interest in improvement of the crop through hybridisation and selection. This discovery led to the establishment of organised breeding work in different countries, the earliest ones during the beginning of the 20th century being in Java, Barbados and India.

Initially the breeding work was concentrated on the two important economic characters of yield of cane and sucrose content. However the ravage of the Sereh disease in Java led to enlisting this character of resistance in the breeding programme. Similarly in India, with the concentration of the sugarcane area in the sub-tropical belt, the need was felt, right from the dawn of the breeding work in the country, on breeding for tolerance to the adverse conditions of drought, frost, water-logging and salinity and later to the diseases redrot and smut. In Louisiana, U.S.A., breeding for resistance to the mosaic disease became important right from the start. More and more specific characters are being added on among the breeding objectives in different countries depending on the local problems.

With very wide breeding objectives, the need arises to understand the peculiar features of the sugarcane crop to enable evolve suitable breeding techniques and methods to achieve the desired results.

The important features of the sugarcane crop may be detailed as: -

1. Clonally propagated and multiplied inclusive of ratooning.
2. Both sexual and asexual reproduction possible.
3. Cross pollinated in nature with possibility of controlled pollination including inbreeding (selfing and sib making).
4. Highly complex polyploid.
5. Large number of small chromosomes creating difficulties in identification.
6. Extremely heterozygous and heterogenous in genetic make up.
7. Crossable with a number of wild and cultivated species and genera with interspecific fertility due to autosyndesis.
8. Special cytogenetical features like sterility and incompatibility mechanisms, functioning of reduced and unreduced gametes, parthenogenesis, maternal inheritance, etc.
9. Long duration of the crop with the vegetative part as the economic product.

Thus besides the peculiar genetical features of the crop, the mode of reproduction, longevity and method of propagation have a bearing on the breeding programme in the crop. We are aware that in sexually propagated plants, the genotype of the selection is most important. In an asexually propagated plant like sugarcane, though breeding behaviour is not unimportant knowledge of the phenotype as seen from the variation introduced and selection assume importance. Genotype maintenance poses no problem.

Thus in the sugarcane crop, the method of breeding would involve: --

1. Choice of parents of initial material as elite clones for breeding.
2. Suitable combinations to produce a suitable phenotype.
3. Handling of a large population in the early seedling generation (seedlings raised from seed).
4. Handling of a large population in the clonal/vegetative generation.

Thus the understanding of the genetics of the crop along with the limitations involved in the breeding and selection systems have led to rapid strides in realising the objectives of the breeding programmes in the various sugarcane growing countries.

Breeding techniques

1. Control of flowering.

The flowering of sugarcane is of considerable interest to the sugarcane breeder and the grower for entirely opposite reasons. For the breeder natural flowering is a must if hybridisation and production of sugarcane varieties have to go on unhampered. For the grower, flowering is considered a disaster in many countries as it stops/lessens vegetative growth and brings down yield and quality and thereby loss of sugar. He would prefer non-flowering varieties.

The factors involved in flowering of sugarcane have been studied by many workers, notably Clements and Coleman who have dealt with this aspect in a series of publications. (Clements, 1975; Coleman 1969). Among the external factors, photoperiod is considered as very important. Sugarcane is a short day plant and flowering occurs when the day length gets reduced with increase in the nyctiperiod. Thus flowering is normally during the onset of winter if the temperature conditions are optimum. In the northern hemisphere, flowering occurs during October - November and in the southern hemisphere during May - June. Flowering is best in the tropical latitudes, particularly 5° to 15° N & S. In the sub-tropics, flowering is less pronounced or absent and pollen fertility very low due to the low temperature. Thus in countries having the sugarcane area in the sub-tropical latitudes like South Africa, Louisiana (U.S.A.), artificial induction of flowering becomes necessary if breeding work has to be undertaken at all. In certain areas, while flowering is possible, pollen fertility is low necessitating the removal of the stalks after floral initiation to a temperature controlled chamber with an ambient temperature around 25° C. Even in situations very favourable for flowering as in Coimbatore (India), some varieties, particularly of the species *S. officinarum* fail to flower and artificial induction becomes necessary.

Flowering in sugarcane is limited to a 7 to 10 day period and the entire flowering season is normally over by 6 – 8 weeks. Some varieties flower early in the season and others late necessitating synchronisation of flowering for successful hybridisation.

Considerable work has been done on the induction of flowering in sugarcane. Chilton and Moreland (1934) adopted a technique based on gradually shortening days which has worked satisfactorily in some countries. The treatment was a day length of twelve hours forty-four minutes plus the twilight period and the day length was reduced by one minute a day using a photoperiodic house. Vijayasaradhy (1956) was able to induce flowering using four hours extra darkness per day after subjecting plants to four hours extra light daily for three months. There have been modifications in these two basic procedures by workers with successful results.

For synchronisation of flowering, several methods have been tried for delaying flowering. These include change in planting time, lopping of leaves during the growing season, use of chemicals and application of overhead lighting to interrupt the dark period at the appropriate time of year.

The sugarcane scientist has been able in a large measure, to solve the problem of induction of flowering in varieties which is a prerequisite to any breeding programme.

2. Isolation of cane stalks.

The bisexual nature of the sugarcane flower, the occurrence of a few thousand such flowers in one inflorescence and the minute nature of the individual flowers impose problems for the breeder in his choice of varieties for use as female or male and for avoiding selfs or contamination. Emasculation is almost impossible except in the case of genetical studies involving raising of a limited number of seedlings. To add to the above difficulties, the height of the inflorescence (often above three meters from ground level) poses limitations on the efficiency of the hybridisation programme.

The first attempt at an easier way of handling the flowers at convenient heights was by Venkatraman (1926) who devised a method of rooting at nodes the standing stalks and removing them. These stalks are then placed in a horizontal position and the flowers are available at convenient height for examination and effecting crosses. This was a great step forward in increasing the efficiency and output of the breeder and also avoiding contamination. An improvement over the method was made by Dutt and Hussainy (1956) who used polythene tubes and moist soil or sphagnum moss for marcotting the arrows. The advantage of this method was that the stalks could be marcotted in knowing the time to flower and in adjusting them at any convenient height. However, a fairly high rate of mortality of stalks has made this method rather uneconomical.

The solution method developed in Hawaii has been popular these forty years and many countries now regularly use this technique for controlled hybridisation work. The standard Hawaiian solution as recommended is 0.03 per cent sulphurous acid and 0.01 per cent phosphoric acid (Verret, 1925). The arrows are cut with several mature joints, all the leaf blades removed and kept in the solution. The two precautions to be taken are regular changing of the preservative solution and renewal of the cut surface at intervals. Several modifications of the original method are being adopted in different countries with satisfactory results.

3. Hybridisation lanterns.

In spite of the advantage of the isolation technique, the reduction in seed setting and mortality of stalks has compelled sugarcane breeders in many countries to continue to effect crosses in the standing crop in spite of obvious disadvantages. Controlled hybridisation using a cover over the female arrow to prevent contamination has been in vogue practically ever since breeding work started. Here again unless the cover allows maximum aeration and no rise in temperature around the flower, seed setting is impaired. This has resulted in the use of huge lanterns in the field wherein both the female and male arrows are enclosed. The classical Barbados lantern of 3' x 3' x 3' was in use for many years with closely woven cloth. Considerable research has gone into the cloth cover and Australian work has shown that even closely knit muslin cloth cannot totally avoid entry of undesired pollen. With the advent of the polythene age, this material has come in handy for use as the bagging material and many countries use polythene in their regular programme. These lanterns are fixed by bamboo or wooden poles and manipulated by pulley arrangement. Since the sugarcane flower normally opens early in the morning as the sun rises, the crossing work is done using lanterns and examining the flowers before effecting crosses. By pre-arrangement, the female and male parents are planted side by side and the arrows enclosed, or the male arrows are cut and placed in the Hawaiian solution by the side of the standing female arrow, or the pollen is collected by clipping the opened flowers and dusted on the female arrow. Three weeks elapse after pollen dusting before the seed setting is complete. There is no dormancy or after ripening in sugarcane and the seed can be sown immediately on collection. The seeds loose viability rather rapidly under ordinary atmospheric conditions. Preservation in Co_2 or under low temperature has helped in prolonging the viability.

Breeding methods

1. General.

It was mentioned earlier that the breeding of sugarcane differs from that of many economic crops in view of its genetic constitution particularly extreme degree of heterozygosity. As a sequel to this position, extreme genetic variation is noticed in the seedling population which is of course a delight to the breeder to make selections therefrom. During the earlier years of the breeding work, mere raising of a large population by using any variety that flowers and without any particular breeding method and making rigid selection in comparison with standard commercial varieties, has yielded good dividends in many of the countries. It was a case of using the best and hoping for the best.

While raising of a large population does continue to be the aim of the breeder for obvious reasons, the advancement in our knowledge of the cytology and genetics of sugarcane has led to an understanding of the breeding material and the limitations and thereby progress has been quicker than by the earlier empirical methods. The Progeny tests have enabled the decision on choice of parents and parental combinations for most effective results per unit time and money output. During the last two decades, studies on the heritability of characters, the specific and general combining ability of parents and crosses have given an insight into the probable genetic advance that can be made.

2. Problems for breeding.

In India, sugarcane is being grown on a commercial scale from latitude 5° to 27° N in all the States except Kashmir, encompassing varied soil and climatic conditions particularly in the two geographical belts - tropics and sub-tropics. Historically the concentration of area under the crop has been in the sub-tropical belt and this continues to be so even today though the industry has expanded in the southern tropics, the area best suited for sugarcane. This concentration of area in the sub-tropical belt brings with it many problems for the sugarcane breeder. In addition to the low yield of cane due to the rigorous climate and the growth period being limited, moisture stress is an important factor in the area and the crop has to face fairly severe drought during the early stages of growth. The heavy monsoon rain very often brings with it a flood in the rivers and consequent waterlogging of the crop. Following this is the winter when growth ceases and the cane crop is expected to accumulate the maximum sugar. Often the temperature tends to be very low with occasional frost and this results in loss of accumulated sugar due to inversion. Redrot disease is a serious problem and perhaps one of the priorities for the breeder in building up resistance in varieties. The borer pest problem can also be severe. The need to extend the factory crushing season poses the problem of evolving varieties with varying ripening periods - early, mid-season and late to obtain uniformly good recovery throughout the season. Pre-and post-harvest technology has assumed importance during recent times and the need for suitable varieties which could stand in the field without deterioration of juice and which would show least deterioration after harvest often accompanied with delays in transport of cane and crushing.

To solve the problems listed above, the country has been divided into seven agro-climatic regions (Bhat 1961) from the point of sugarcane growing and evolving varieties by breeding.

3. Breeding systems.

The use of the wild sugarcane *S. spontaneum* led to a breakthrough in the matter of yield of cane and tolerance/resistance to adverse environmental factors and certain diseases and pests. Interspecific hybridisation using the three species of *Saccharum* - *S. officinarum, S. barberi* and *S. spontaneum* has been the mainstay of the breeding work in the early thirties. *S. officinarum* has been the donor for quality while *S. spontaneum* was expected to confer tillering and resistance to diseases and adverse agronomic conditions.

Inter-generic crosses have been attempted with the allied genera *Sclerostachya, Narenga* and *Erianthus* (now *Ripidium*) in order to obtain water-logging tolerance. Though these genera have been known to confer this character to the progeny, the need to back-cross for a number of generations for obtaining a commercial type has placed a limitation on this method.

The use of *Sorghum* and *Zea Mays* in crosses with sugarcane was for evolving early maturing varieties. While there is evidence that the crosses are genuine, problems connected with sterility in the F_1 progeny and failure to flower in the maize cross and the need for a large number of back crosses place a limitation on this programme particularly when the grower and the miller clamour for quick replacement of varieties.

Excellent results have been obtained by the back cross method for obtaining resistance to diseases, particularly smut.

A more recent development for exploiting specific combining ability of crosses in respect to earliness has been the recurrent selection programme. The programme aims at selecting for earliness in the progenies and intercrossing in the second cycle of such early segregants with desirable agronomic characters.

The two negatively associated characters of yield and quality are sought to be combined through a Reciprocal Recurrent Selection Programme by exploiting both general combining ability of the parents and specific combining ability of the crosses. High yielding parents are intercrossed with high quality ones in all possible combinations including reciprocals. (Thuljaram Rao and Krishnamurthy, 1968).

It has been found that sugarcane is less sensitive to mutagenic agents (both physical and chemical) as compared to other crops because of the high level of ploidy. General chronic, high dosage, long duration treatments are necessary. There is also the difficulty in distinguishing a segregation in M_2 from a normal genetic variation. Chemical mutagens and isotopes have been studied but beyond morphological variations like stripes, glabrous leaf sheath, etc. no advantages have been obtained in economic characters.

Irradiation through gamma rays may be a promising approach though the end may not justify the inputs involved. An economic mutant of Co 449 with redrot resistance has been obtained by irradiation (Thuljaram Rao, Srinivasan and Alexander, 1966). Similarly a redrot resistant mutant of Co 997 has been obtained.

The use of tissue culture to obtain mutants has been recently taken up, encouraged by studies elsewhere that tissue free from mosaic has been obtained from infected material.

In sugarcane where a large population, often running to 100,000 every year has to be screened and useless genotypes eliminated, artificial techniques for rapid screening of seedlings for diseases and correlation of characters assume importance. The phenolic content in juice and polyphenol oxidase activity is correlated with redrot resistance (Chiranjivi Rao, 1968). The cation exchange capacity of roots has shown relationship with yield (Thuljaram Rao, Krishnamurthy and Chiranjivi Rao, 1967). Nitrate Reductase activity (Chiranjivi Rao and Lalitha, 1971) has shown relationship with quality. Proline content seems to be associated with drought resistance. (ANON, 1975).

4. Germ plasm.

The wealth of a plant breeder is his germ plasm. With the advantage gained by use of the wild *S. spontaneum* in the breeding programme, the need to explore this species was keenly felt and the Coimbatore Institute by personal exploration has collected over 400 types of this species from all over India, Africa and South East Asia. These clones vary considerably in morphology and cytology and have been studied thoroughly for all characters (Panje, 1971). Selected clones are in the process of being utilised in breeding and needless to say the exploitation and evaluation of this species as breeding material will involve many years of study.

Similarly, over 600 clones of the species *S. officinarum*, the donor for quality have been collected from the Melanesian islands through explorations, the latest being the 1976 one in

Indonesia. These are under intensive study and those which flower used in breeding.

The second wild species of sugarcane, *S. robustum* is also under study.

The Coimbatore Institute maintains a world germ plasm collection of sugarcane numbering over 2,500. The second world collection is being maintained at Canal Point, Florida, U.S.A.

Results of breeding

The only Institute in India dealing with the breeding of sugarcane, the Sugarcane Breeding Institute at Coimbatore was started in 1912, sixty-five years ago to fulfil the urgent need to evolve suitable improved sugarcane varieties for the sub-tropical region of the country where the crop is being grown over nearly 90 per cent of the area. The indigenous varieties which were then under cultivation were poor in yield with hardly 5 – 6 tons of cane per acre as compared to the 20 – 25 tons in other countries though tolerant to the adverse climatic conditions of drought and frost and also diseases and pests. The country was then in the pitiable state of having to import large quantities of sugar, mostly from Java (now Indonesia) draining the exchequer. Coimbatore was chosen as the venue for the breeding work, over 1,500 miles from the sugarcane belt since sugarcane flowers and sets seed freely under the climatic conditions.

The Institute, by using the wild relative of sugarcane, *Saccharum spontaneum* (Kans, Dharba) in the breeding programme, for the first time in the world, was able to release, within a short span of six years since its inception, a number of varieties which gave a yield of 50 per cent over the indigenous varieties in addition to tolerance to the adverse climatic conditions, diseases and pests. Notable among the improved varieties which were in cultivation during the 1920s and 1930s are, Co 205, Co 213, Co 281, Co 285, Co 290, etc. which replaced the indigenous varieties to such an extent that by 1930, the area occupied by the improved varieties was over 90 per cent under the crop. Further improvements by use of new varieties in breeding resulted in the famous varieties, Co 312, Co 313 in North India which sustained the sugar industry in Uttar Pradesh and Bihar. By 1930, the area under sugarcane increased in tropical India and the world famous variety Co 419 was released from the Institute in 1936 and occupied practically the entire area south of the Vindhya mountains. The variety was so versatile in performance that it was in commercial cultivation in the then British West Indies Islands, Mexico and other countries. The variety Co 281 was the mainstay in Louisiana (U.S.A.) and South Africa on account of its good performance and Co 290 in Hawaii and Australia.

Newer and newer improved varieties are being evolved every year and the new ones replace the older varieties. Among the current varieties, mention may be made of Co 1148, Co 1158 in the sub-tropical region, Co 6304, Co 62175, Co 6415 in the southern States which are superior to the earlier varieties from the point of yield of cane and sugar.

Recently attention has been devoted to evolving early maturing varieties and in this connection, a variety, Co 7704 has been evolved last year which is expected to give good yield and recovery at eight months with the possibility of having three crops of sugarcane in two years. Other early varieties which are good are Co C 67-1 and Co A 7601. Thus the prospects of the factories starting with early varieties and satisfactory recovery are bright.

The Institute has established a National Hybridisation Garden in which all the sugarcane growing States are free to carry out their hybridisation programme and collect hybrid seed and sow in their local conditions. Last year hybrid seed capable of raising 17 lakh seedlings was sent to the State Research Stations thus affording a wide variation to select from. With this massive expanded programme, it is expected that a new variety may be available for commercial cultivation in each of the agro-climatic regions once in five years, aiding in the increase of sugar per unit area.

The best evidence of the results of the Institute is a stabilised sugar industry as we see today in this country and India is in a position to export sugar and earn foreign exchange. It is well known that in 1975–76, the export of sugar topped all commodities in getting a record foreign exchange. The growth of the sugar industry during the short span of 40 years has been phenomenal. From about 3.0 lakhs acres under cane in the thirties, we have now about 60 lakhs acres. The 30 sugar factories in 1930 have swelled to 250 now. The sugar production has gone up from 2.0 lakh tons to a record figure of 47 lakh tons in 1974–75. All this has been possible, due to the Coimbatore Institute placing in the hands of the growers and the millers, improved varieties with good yield and sugar. It is no exaggeration to say that the work of the Institute through the famous Co varieties is a household name with the sugarcane growers in the country and in many sugarcane growing countries in the world.

In a recent survey conducted in U.S.A. on the input - output ratio and also cost benefit ratio through research in crops, it has been found that the sugarcane research work conducted at Sugarcane Breeding Institute, Coimbatore, in evolving the improved hybrid Co varieties has given the maximum results.

The Institute has two Regional Centres one at Karnal (Haryana) and the other at Cannanore (Kerala). The Karnal Centre is meant to provide feed back information to the main Institute with regard to parental stocks for use in breeding for the north Indian conditions. This is mainly done by having the germ plasm collection of 2,000 clones in Karnal and assessing them for drought and frost tolerance as also top borer and redrot disease. Also Karnal is the best place for working on horizontal resistance of sugarcane to redrot disease.

The Cannanore Centre houses the world germ plasm collection, one of the two in the world where 2,500 collections are available for study and use in breeding.

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Discussion

G. S. Khush, The Philippines: You mentioned the difficulties in hybridization due to plant height. Isn't it possible to cut the inflorescences, put them in water containers, and carry out the crosses in the laboratory?

Answer: Yes. It is possible and marcotting can be done to isolate sugar cane stalks for hybridisation. In Hawaii, the solution method is being used. Seed-setting in isolated stalks is not as high as in normal stalks and mortality rate is rather high. Hence field-crossing is usually performed.

M. Kudo, Japan: Only one variety of smut disease has been reported in Japan, while race differentiation has been reported in Taiwan and Hawaii. What is the situation in India?

Answer: Race differentiation in smut has been reported in India. As regards control, smut disease can be easily taken care of if one rogues the affected clumps and get healthy seeds. In order to screen varieties for the disease, one can soak buds in a smut spore suspension and observe the reaction.

K. Sakai, Japan:

1. I remember that Dr. Parthasavathy had observed separate behaviour of two sets of chromosomes coming from both parents in a meiotic division. As you are interested in interspecific crossings, have you observed such a phenomenon in your hybridisation work?

2. Sugar cane can be grown commercially as a clone. Therefore, I wonder why you are more interested in general combining ability than in specific one.

Answer:

1. Parthasavathy has reported the autosyndetic behaviour of sugarcane which helps in the fertility of even interspecific crosses in the crop. He has also reported the behaviour of unreduced gametes when *S. officinarum* is used instead of *S. spontaneum*.

2. In the recurrent selection programme you are referring to, we take into account the general combining abibity of the parents and the specific combining ability of the crosses.

G. S. Khush, The Philippines: You mentioned breeding for horizontal and vertical resistance in sugar cane. How do you differentiate between the two?

Answer: It is said that sugarcane is an ideal material for working on horizontal resistance. While vertical resistance is temporary and specific to strains, horizontal resistance is more permanent and involve resistance to a few or to many strains. This is the basis for the programme involving resistance to red-rot disease.