SOME ASPECTS OF SUGARCANE BREEDING IN RELATION TO ITS CYTO-GENETICAL PECULIARITIES

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THE methods followed in sugarcane breeding are necessarily a consequence of its cyto-genetical features. Inbreeding and pure-line selection are almost impossible. The presence of a large accumulation of recessive lethal genes, results in there being practically no survivals in the selfed progeny. Compared to the basic chromosome number 10 for the tribe to which sugarcane belongs, the different species of *Saccharum* are high multiples thereof. *S. officinarum* of which we have a collection of more than 150 varieties are octoploids except Kajla which shows $2n = 68$. In *S. barberi* within which there are four well-defined groups the chromosome numbers vary from 82 to 140. In *S. robustum* the range of chromosome numbers is from 60 to 144. In *S. sinense*, 118 to 122. In *S. spontaneum* it is 54 to 128. Thus the simplest material available shows a high degree of genetical impurity. Orthodox methods of breeding in such highly heterozygous polyploid complexes can be of no avail. While autosyndesis makes segregation along Mendelian expectation almost impossible, it also confers the advantage of wide crossability provided the parental chromosomes are compatible enough to co-exist alongside of one another in the hybrid complement. Such wide crosses with bamboo, *Sorghum*, maize, *Sclerostachya* and *Narenga* are traceable to this phenomenon. The ultimate effect of all this and other features to be mentioned later down, is that there is bound to be a large element of chance in sugarcane breeding which cannot by any means be eliminated altogether.

While these are to be expected in forms of the genetical make-up of sugarcanes, there are certain features which may be regarded as unique some of which are of direct importance in sugarcane breeding. Of these the most recently noticed is the phenomenon of cytoplasmic inheritance (Raghavan, 1951 *a*). Neither a wholly maternal inheritance nor its universality is suggested. There does however, appear to be an interaction between the genes and the plasmon resulting in a configuration leaning more towards the mother than to the father, not easily explicable on the basis of purely genic inheritance. This would appear to explain why in several

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hybrids there is very little expression of the male characters irrespective of the number of chromosomes contributed by either parent. For instance recently two seedlings were derived from a cross between sugarcane and bamboo (Raghavan, 1952). This cross was different from those made previously (Venkatraman, 1937), in that for the first time, a pure *officinarum* (var. Vellai) was used as the mother instead of complicated bispecies and trispecies hybrids like Co. or POJ. canes. The gross resemblance of both was to the sugarcane. One was thick and the other thin. The former came into being by the union of a diploid egg with the sperm of bamboo. In the latter it is presumed that an egg with an unexpected number of chromosomes has functioned. Apart from chromosome numbers there are a few characters of the male parent which point to the seedlings being genuine hybrids, like the arched root eyes, the bud piercing through the sheath, underground branching of stem, etc. Even so the hybrids are cane-like. Nor can it be generalised as a rule that the thinness of the second hybrid is due to its having received lesser number of chromosomes from the mother. For cases are known where in the same cross hybrids have come into being having chromosomes $2n$ from the egg and $2n$ from the sperm, and $2n$ from the egg and n from sperm. And yet the general configuration of all the hybrids is more or less similar showing that the dosage effect of certain of the parental chromosomes is very limited. The latest known such case is *S. spontaneum* × Sweet *Sorghum* ($2n = 74$ and $2n = 84$); in *S. officinarum* var. Chittan × *Sclerostachya* and *Saccharum robustum* × *Sclerostachya* both $n + n$ and $n + 2n$ hybrids have been got but with no phenotypic differences (Raghavan, unpublished). On the other hand, there are crosses, where seedlings of a cross, though having the same chromosome number, show different phenotypic expressions, *e.g.*, *S. officinarum* var. Zw. Cheribon × *S. spontaneum* ($2n = 112$). If, however, a detailed study of the characters and their inheritance is made, it is possible to classify them into three— those which are affected by dosage of genes, those showing complete dominance and those showing no definite pattern of inheritance. Of these the last named is preponderant. These discrepancies can only be explained on the basis of an inheritance which is neither purely gene-controlled nor purely maternal, but a result of an interaction between the genes and the maternal cytoplasm. From this point of view, it is reasonable to bestow more care to the mother than to the father in sugarcane breeding.

Another phenomenon which is likely to play an increasingly important part in sugarcane breeding is parthenogenesis. It is known that when self-sterile or pollen-sterile forms of Co. or POJ canes or selfed are dusted with pollen from distant genera, the latter acts as a stimulus and induces diploid

parthenogenesis. In pure *officinarum* the flowering is so rare and erratic that it has not been studied properly so far. Also the presence of a large number of recessive lethal genes makes survivals few. The exact method of coming into being of an unreduced egg is not known definitely. It is likely to be through endomitosis in the basal spore of the linear tetrad, such as Bremer (1948) has indicated. Narayanaswamy (1940) has said that there takes place a fusion of the two basal spores of the linear tetrad. It has not yet been possible to confirm this finding. In either case, the most important point is that the diploid spore and from it the diploid egg, comes into being not through suppression of meiosis, but is the result of a post-meiotic process, and as such tantamount to fertilisation. So all the vagaries that one can expect in seedlings arising out of fertilisation in a polyploid complex like sugarcane, can be expected in parthenogenetic derivatives as well. And that is what we find. A number of Co. canes having well-known pollen-sterile forms as mother—and generally only such forms are used provided they are otherwise desirable—were examined cytologically and they showed the maternal somatic number indicating their parthenogenetic origin. For example, Co. 462, Co. 463, Co. 656, Co. 779, have all arisen from Co. 421, a pollen sterile form and show only the maternal diploid number 118, even though the staminate parent used in each case has been different. So also Co. 678, Co. 797, Co. 798 and Co. 811 which have presumably arisen parthenogenetically from Co. 603. The very fact of their being different Co. cane numbers is itself proof of the fact that they are widely different from one another. All these variations are a consequence of parthenogenesis being almost a substitute for fertilisation in sugarcane. There are so many chromosomes in the polyploid complex and the pairing autosyndetic, that the resulting phenotypic configurations are many and unpredictable, even though they are all derived parthenogenetically. In addition to diploid parthenogenetic derivatives a few cases are known where daughter seedlings have come into being containing neither the diploid number nor the haploid number. Usually they contain a number less than the diploid number and more than the haploid. The latest known case is that of Co. 602 ($2n = 118$). In selfs of this, we get two types of seedlings, one having the diploid number and the other having $2n = 96$. Obviously 11 bivalents have been eliminated and the remaining 48 bivalents have undergone doubling through endomitosis. The case of *S. officinarum* D. 74 ($2n = 80$) × *S. spontaneum* ($2n = 64$) giving seedlings with 112 and one with $2n = 60$ may also be interpreted on the basis that the former are crosses ($2n + n$), but that the latter are a product of parthenogenesis from an egg with 60 chromosomes. The same is the case with Co. 421 ($2n = 118$) from which in addition to diploid plants, a

few having $2n = 86$ were got (Parthasarathy, 1946; Subramaniam, 1946). It means that not only has chromosome elimination taken place *en bloc* but also side by side, a process of doubling of the functioning group of chromosomes through endomitosis (Parthasarathy, 1951). These two oppos-ing processes of deletion and doubling bring into existence new chromosome races exhibiting a wide range of variability. This is bound to play a very important part in sugarcane breeding. That the sugarcanes are able to withstand such elimination *en bloc* is due to their high polyploidy.

Very recently there was observed a case where two parthenogenetic derivatives from *S. officinarum* var. Striped Vellai, showed a number higher than the diploid number (Raghavan, unpublished). How exactly the egg came to possess this number is not known. But this only makes the prob-lem more interesting and it looks as though that in sugarcane breed-ing parthenogenesis has played and is playing a more important part than has hitherto been surmised.

There is also evidence of such eggs brought into being through these opposing forces of numerical diminution and multiplication of chromo-somes and therefore having neither the haploid nor the diploid number, taking part in fertilisation. Co. 453 a thickish cane, now becoming popular in North India (some parts of Uttar Pradesh and Bihar) is one such (Raghavan, 1951 *b*).

In applying the laws of genetics to sugarcane breeding, one is confronted with the difficulties that one may expect in dealing with a plant of its genetical constitution, *e.g.*, the simplest material available is highly polyploid with an equally high degree of genetical impurity and as such there is generally an absence of Mendelian segregation on expected lines due to autosyndesis. The important genes in sugarcane are those controlling the physiological rather than morphological reaction—sucrose content, disease resistance, etc., and these are characters which cannot be easily identified.

In addition to these inherent difficulties, the special cytogenetical features characteristic of sugarcane of which some idea has been given only tend to make breeding more complicated and unpredictable.

The discovery of an increasingly larger element of chance seems inevita-ble in sugarcane breeding as more details come to light of its cyto-genetics.

The main problem therefore is to bring sugarcane breeding within the operation of laws of Mendelian Heredity. This can be achieved by reforma-tion of the original but unknown diploid progenitor. With such simplifica-tion a high degree of genetical purity may be expected to be restored. One

step towards such a simplification is haploid parthenogenesis of which no sign exists so far. Chromosome elimination *en bloc* such as has been described may perhaps be made use of in some manner. Another way is by continued back-crossing with forms which are likely to have played a part in the origin of sugarcane. This is being done. But the problem is to bring about an elimination of all chromosomes other than those of sugarcane. Studies of the meiotic configuration in such back-crossed progeny have indicated the possibility of *Sclerostachya, Narenga, Sorghum* and perhaps *Erinathus* having entered into the constitution of the progenitors of *S. officinarum* (Raghavan, 1951 c).

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