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Recent Advances in Cytogenetics*

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Plant breeding is actively concerned with the so-called improvement of Agricultural Crops. Vavilov defined Plant Breeding as an art, a science and a branch of agricultural practice. He was of opinion that a knowledge of genetics was not indispensable to a breeder; that evolutionary practices permeate the whole science of breeding and that in effect breeding was man's interference in the morphological formation of animals and plants. In other words it is evolution directed by the will of man. But breeding and genetics interpenetrate since they treat heredity and variation. The modern genetics and cytology again interpenetrate. Thus the new line of study Cytogenetics has sprung up. The modern plant breeding has to a large extent ceased to be an art. With cognate sciences it has attained a high complexity and become more exact. Cytogenetics though recent has grown so rapidly and has covered such a large number of cultivated species that it is well nigh impossible to summarise all knowledge in a short paper. Therefore in this paper are presented some of the trends in plant breeding.

The most reliable source of plant improvement is by gene-recombinations. The simple concept of the gene viz., one gene controlling a single factor expression has changed entirely. The genes undergo evolution in the course of succeeding generations. Thus there are far more genes newly added in the existing species than the ancestors ever started with. Though for many genetical purposes the simple older idea suffices, yet the newer results of analyses require us to change this concept. It is still in a speculative condition and it is conceived as of a biochemical unit but self reproducing. Its action thought specific, may vary with the position effect. Therefore it has to be viewed from both the physiological as well as the biochemical stand points. Sometimes a gene may be found to contain lesser genes and may result in a pleiotropic action. The phenotype responds to the environment (Darlington and Mather 1950). In cotton the hairy character of the leaf is known to be controlled by a major gene and a number of minor genes.

Turesson (1923) advanced the theory of Genecology. By this is meant the study of the species-ecology. From this point of view

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of Genecology the Linnean species represents a genetical complex community, the distribution and composition of which is largely determined by the ecological factors and the genotypical constitution of the individuals comprising the species community. The concept of the species from this point of view represents an intercrossing community, the members of which had become clustered in groups (eco-types) on account of the differentiating effect of environmental factors upon the genotypically heterozygous population. The object may be stated as investigation into the grouping in nature of individuals into ecospecies and ecotypes representing various combinations of mendelian factors and the causes controlling this grouping. A point of interest in Genecology is the rarity of interlinnean species hybrids in nature, though they hybridise under experimental conditions, the distributional peculiarities of these hybrids, their localisation at isolated points within the region covered by the parents, their sporadic occurrence between the distributional areas of the parent species and the tendency of certain hybrids to increase when nature is disturbed by man. The mechanism at work here is thus crossing, recombination and selection promoted by spontaneous mutation (Muntzing 1951).

Apart from the nuclear controlled inheritance the cytoplasm has come to play an increasingly important role. Thus definite genes have been advanced called Plasma-genes which are also self-reproducing. The inheritance of the plastid has also been referred to self-propagating bodies called Plasto-genes present in cytoplasm. Their action may be controlled or influenced by the nucleus. The cytoplasm thus exerts great influence on the gene-action and vice versa. This has developed now into the Plasmon theory. Male sterility may be induced by definite plasmons (sorghum, maize, cumbu, onion and tomato). Further the differential behaviour of the hybrids in reciprocal crosses is alleged to the action of cytoplasm.

The next complexity usually arises by either the process of elimination or addition in the heritable material, changes involving the chromosomes may reflect on the phenotype. The older concept of the arrangement of the genes on the chromosomes as a string of beads has altered. Instead of its being conceived as a point on the chromsome, it is more a region of the chromosome. Thus the gene is "a field of co-ordinated activity the property of full activity being conditioned by internal arrangement but independent of external conditions."

Normally polypoids are supposed to show an increase in the gene quantity whether it be by auto or allopolyploidy. It is known that polyploidy endows a plant with increased variability and certain advantages over the diploid. Autoploidy induces the so-called gigas characters. The disadvantage in breeding further from an autoploid lies in its reduced fertility. Alloploid results from species and inter-generic hybridisation resulting in the combination of different plants. When sterility occurs in interspecific or inter-generic hybrids it is found that duplication of the chromosomes restores often the fertility. Thus an interest was stimulated in the artificial production of polyploids for breeding purposes. It was only in 1937 the most successful method of producing polyploids by means of colchicine treatment of plants was discovered by Blakeslee and Avery. Since then though autopolyploids were produced in many economic plants so for only a few have yielded plants of economic value viz., rye, beet, turnip, lucerne, tomato. In paddy the autopolyploids have given varying results depending upon the parental material, but there has been no marked increase in variability. On the other hand, in Cumbu, variability has increased manyfold and in addition perenniality has stepped in.

This dicovery of chromosomal duplication by colchicine treatment has increased the range of utilisation of incompatible interspecific and intergeneric crosses. Also polyploidy itself brings in a greater possibility of intercrossing, which is not usually possible at the diploid level. Thus in cotton the fertile amphidiploid of a partially sterile hybrid of *G. anomalum* (African wild cotton) x *G. arboreum* var. *neglectum* (K. 1 a short stapled, commercial cotton) gave a fertile hybrid with *G. hirsutum* (Co. 2. An American long stapled cotton). Similar hybrids were obtained by Harland (1940) between the amphidiploid of *G. arboreum* x *G. thurberii* and a new world cotton, These hybrids present great scope for further selections of recombinations. The amphidiploids may also directly give economic plants. Triticale, Agrotricum, amphidiploid of Cumbu x Napier grass have yielded new types of grain and fodder plants. A synthesised winter turnip rape (the amphidiploid of *Brassica rapa oleifera* x *B. oleracea* the cabbage) has given higher yield of oil by 25 to 30% over the control (Muntzing 1951). Polyploidy, grafting, and the use of bridging parent have been employed with success for overcoming incompatibility barriers between distantly related plants.

The chromosomal study in the haploids and hybrids has given a clue to the true nature of the present day economic plants. It is interesting to find that most of the cultivated crop plants have arisen in nature as sterile hybrids of distantly related parents followed by chromosome duplication. Thus it has been possible to synthesise the existing species by hybridisation of other Linnean species e.g. *Galeopsis tetrahit* (Muntzing 1930), *Primula kewensis* (Newton and Pellew 1929). The cultivated Indian mustard *B. juncea* is shown to have originated from a sterile interspecific hybrid between *B. campestris* and *B. nigra* followed by amphidiploidy as also tobacco *(N. sylvestris* x *N. tomentosa)* and the tetraploid American cottons are of amphidiploid origin with one genome ancestral to Asiatic and another to the New world. The cultivated bread wheat is made up of two cultivated wheats viz., einkorn and emmer plus a wild species *Aegilops squarrosa.* It has been found that several wild species like *S. spontaneum*, and *Sclerostachya* sp. played a role in the building up of the modern sugarcane.

Induction of changes in the game has been attempted by both physical and chemical means. These are aimed at production of a chemical change resulting in a newer expression of the gene or the arrangement of the gene in a chromosome, deletion, duplication, inversion segmental interchange etc. Knight (1948) was able to transfer black arm disease resistance from one species of cotton to another by chromomome fragmentation and recombination. Some of the chemicals that have been used as mutagens are caffeins, camphor products, coumarin, acenaphthene, mustard-gas products, colchicine, some of the narcotics etc. Heat and cold shocks and irradiation with X-rays and radioactive substance are the physical means frequently employed. Of these the most powerful agent has been irradiation with X-rays. The number of mutations produced are numerous, many being uneconomical yet with careful selection highly ecconomical ones could be obtained. (rye, rape and barley). It could also be very usefully applied in the case of horticultural plants which are vegetatively propagated. Positive results have been obtained in the case of apples.

Disease resistant types have been built up by the method of hybridisation and back crossing or hybridisation, production of amphidiploids and back crossing. Back-crossing itself has gained a new and important application in modern plant breeding. Judicious back crossing can result in either substitution of a genome or part of it or the restoration of a particular genome in the species hybrids. Thus in the case of *N. tabacum* it has been possible to incorporate into it the mosaic resistance found in *N. glutinosa*. By the technique of back crossing improved varieties of maize have been produced inspite of its heterozygosity. In cotton it has been possible to build together in the same plant resistance to jassids as also black arm disease. The hybrid of *P. typhoides* with *P. purpureum* has combined in itself resistance to rust and *Helminthosporium sacchari*. Similarly blast resistance in paddy has been built up from the hybrid of a resistant poor yielding variety with a high yielding one.

Still another type of abnormality is the phenomenon of apomixis. It may be obligatory or facultative. Mango, citrus and certain grasses are known to be facultatively apomictic. By this means, may be obtained both the sexual embryo and a number of asexual ones the latter alone repeating the maternal characters. Mangosteen is an example of obligatory apomict. In this species plants producing anthers are not known. By isolation of such obligatory apomict races it is possible to propagate a variety overcoming the chances of segregation. Apomixis is often induced by higher polyploidy following hybridisation and constant vegetative propagation.

One of the chief delimiting factors for wide crosses is the failure of the zygote to develop further. Successful pollination and even fertilisation may occur. The embryo placed as it is in an incompatible or early disorganising endosperm may fail to grow further as a result of certain toxic substances produced by the endosperm. This has been the stumbling block in effecting many much desired crosses between certain plants. A technique has now been developed with the help of which it is possible to remove the young embryos even less than a weak old ones and grow them in artificial medium under sterile conditions. This technique has generally been called embryoculture. Successful cultures, however, have been still restricted to very few crop plants. The Russians have claimed that they were able to graft different cereals even at the embryonic stage when the seedlings just start growing.

Many fruits are sought to be bred for greater pulpyness and reduction of the seeds as far as possible, the variety being propagated vegetatively. Seedlessness has been found to be due to two causes. One it is gene controlled. The other can be induced by bringing in disturbances in chromosomal balance such as triploidy. In this case the production of inviable gametes prevents the formation of seeds. The stone fruits have not yielded for breeding of seedless character. Parthenocarpy is another phenomenon which is genetically controlled as in the case of banana. This is independent of chromosomal unbalance. Certain chemicals and hormones have been found to produce parthenocarpic development of fruits as in tomato etc.

Heterosis or hybrid vigour has been much in the picture for some time. The discovery in maize of production of plants with greater vigour and yield on hybridisation of two inbred lines has given rise to its application in quite a large number of plants. The question arises whether hybrid vigour is expressible in strictly self-fertilized plants. Its effect has now been commercially applied in the case of maize, brinjal, sugar beet, cumbu, tomato etc. In the case of plants which are hermaphrodites emasculation becomes necessary. In such cases male sterility can be induced by irradiation with X-rays. More recently the cytoplasmic induced male sterility is also being exploited for production of hybrid seeds. Apart from these few cases mentioned numerous other advances have occurred in the methods of plant breeding and hybridisation. It has been possible to breed for special purposes. In the achievement of these objects there has been a persistent effort by numerous workers at collection of materials of crop plants from their original homes. Thus an extensive arboretum was maintained by Vavilov in Russia consisting of several thousands of varieties of a single cultivated crop. By such extensive collection and studies on these living specimens it has been possible to trace to a certain extent the origin and spread of a few of the cultivated crop plants. The production of new plants to meet newer conditions either pathogenic or environmental calls in co-ordinated research of all branches of agricultural sciences.

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