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SELECTED ARTICLE

Plant Breeding and Genetical Work in India.*

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I. Introduction.

The President of this section last year made a departure from the usual custom of confining the address to a branch of the subject he was most familiar with and gave instead an address on a general review of the progress of agriculture. I shall, however, revert to the usual practice. Last year's address had a large portion of it devoted to the value and care of seed. It is probably in the fitness of things that my address deals with the problem of search for, and production of seed with inherent superior characteristics. I shall make a general survey of the plant breeding and genetical work in India and in doing so, refer largely to two crops, rice and cotton, with which I am most familiar.

Scientific breeding with crop plants has become a powerful and indispensable tool for making agriculture more efficient and more flexible in meeting new demands and supplying the needs of men for food and raw material. "In the realm of living things with which agriculture deals, the work of the breeder is comparable to the work of the inventor in the realm of inanimate things with which industry deals, and his work pays in the same way that invention pays by replacing continuously the old by the new or making possible what was not possible before". The growing of improved types involves no additional expense to the cultivator and the work of breeding improved types has formed an important plank in the activities of the agricultural departments right from the very beginning.

Plant breeding in its strict sense means the production of better crops, the ultimate test of superiority, with exceptions, being greater yield per unit area and hence greater return to the grower. In the case of industrial crops like cotton, besides yield, the question of quality also comes into consideration in deciding the return per acre and hence breeding for quality does form part of the breeder's objective. At the present time breeding for quality in cotton has become an urgent necessity in several tracts since the bulk of the cotton produced in India is of short staple, the outside market for which has considerably dwindled. Breeding for quality in food crops, cereals, is still not of much importance in our country as the term 'quality' is incapable of a precise definition and usually has no bearing on the nutritive value. To mention only one example, the quality in rice, as is commonly understood, depends upon the size and colour of the grain and upon the extent of polishing it has received. Quality from the nutritional point of view is, however, quite different and if practical effect is to be given to the findings of research work on this problem, (Ramiah *et al.*, 1939) we shall have to radically change our ideas about quality in this most important food crop of the country.

Even in industrial crops, for various reasons beyond the control of the grower, yield under Indian conditions still forms the predominant factor. Let me try to illustrate this with a small example in cotton. The local indigenous cotton grown in Central India is of a poor quality, the lint capable of spinning only 10—12 counts. There is, however, the Upland cotton, which is definitely superior to the indigenous in quality and commands a better price in the local market but does not yield quite so well as the indigenous as a rain-fed crop.

* Presidential Address, Agricultural Section, at the 28th Indian Science Congress, Benares, January 1941.

Examination of extensive data on spinning quality and market price for cotton (Panse, 1940*c*) has brought out the fact that the premium obtained for the superior quality of Upland cotton can compensate only a ten per cent. reduction in yield while field trials have shown that the reduction in yield by substituting indigenous cotton with Upland is much greater than this figure, and hence it is not profitable to grow Upland cotton in Central India on rain-fed land.

II. A Survey of Plant Breeding Results.

i. *Results of plant breeding.* Scientific plant breeding, which is not more than thirty years old in India, has been carried on along the traditional lines of selection, introduction and hybridization. In fact, the methods followed are the same that have been followed in the West and the principles involved, which are fundamental, are applicable to all plants in general. It may be worth while at this stage to take stock of the practical results that have emerged so far from this plant breeding work. The only measure of success of this work is the total area occupied by the improved types in various parts of the country Taking India as a whole, the total area under the four important crops and the area devoted to the improved types evolved by the Departments of Agriculture are given below for the year 1937—38.

Crop.	Total area (acres) under the crop, (*thousands*).	Area (acres) devoted to improved strains, (*thousands*).	Percentage.
Rice	72,277	3,759	5·2
Wheat	35,618	6,930	19·5
Cotton	25,583	5,672	22·2
Sugarcane ...	3,818	2,855	74·8

The area under the improved types of sugarcane is very striking because the superiority of these types over the local, which these have replaced, has been phenomenal. In fact, the benefit that the country has gained by the results of plant breeding in this one crop, which can be valued in several crores of rupees has become a classical example of plant breeding achievement, the credit for which goes, in a large measure, to one of our own members and an ex-President of the Congress, Rao Bahadur T. S. Venkataraman. It may be mentioned in this connection that the protection given to this crop has been an important contributory cause for the rapid spread of improved types of sugarcane. That the area under improved types in other crops is not so striking is due to various causes. For one thing, except in the case of cotton and sugarcane, it is so difficult to estimate with any degree of accuracy the area under the improved types, the figures given above, being only rough approximations. Though the percentage area under improved varieties of rice is not considerable taking the country as a whole, it is certainly very much higher in individual Provinces like Madras and Bengal where plant breeding has been carried on in this crop for a considerably longer period than in other Provinces.

ii. *Spread of improved types.* Botanists working in the departments of agriculture might produce better types of crops by breeding, but owing to the peculiar conditions in which Indian Agriculture is carried on, small and scattered holdings, the special tenancy systems, financial instability of the grower, the necessity to sell the produce with the seed as in cotton, etc., it is almost impossible for every individual cultivator to multiply his own seed from the improved types and an organization is necessary to make such seed available to the cultivator. The extent of such organization varies in different Provinces and States in India. While some Provinces like the Punjab spend several lakhs of rupees every year in the multiplication and distribution of seed of improved varieties, there is hardly any expenditure under this item in some other Provinces. It must be mentioned here that the amount involved is not a gross expenditure to Government, but only represents a sum invested and later recouped by the sale of the seed. Owing to sudden fluctuations in the market prices, particularly in industrial crops, it is possible there may be a small loss incurred, in certain seasons, but, considering the practical benefit realized, the loss, even if there should be any, can be safely ignored. In the case of cotton, the Indian Central Cotton Committee finances several seed distribution schemes in different Provinces and States. Because of the limited funds at the disposal of the Imperial Council of Agricultural Research, they were mainly concerned with financing research schemes and now that the resources of this body are likely to be augmented, it is up to them to see whether they should not initiate and partly finance seed distribution schemes also in cases where such help should prove necessary and useful.

We cannot, unfortunately, compare ourselves with countries in the West on this question. There, the multiplication of improved types of crops and making them available to the cultivator is carried out by professional seedsmen as a business. In fact, in countries like Denmark and Sweden, the seedsmen themselves do the work of breeding superior types. Most of the advanced countries have also Seed Acts in force prohibiting growers from using seed which is not pure and certified. The only non official organization that might take up this work is special Co-operative Societies and although a certain amount of such work is being done in India, the output forms an infinitesimal proportion of the total requirements.

Any increase in yield which does not come up to ten per cent is rather difficult to be appreciated by the cultivators and in fact, this is the minimum figure aimed at by most plant breeders under ordinary methods of cultivation. In several cases, the improvement claimed by the breeder as a result of extensive trials, is much above this figure. It is generally the experience of plant breeders that improved types respond very much better than the unselected types to more intensive methods of cultivation.

Of the four crops mentioned above, dropping out sugarcane where the area under improved types is very high and has hence markedly increased the output in the country, the question may be raised whether on account of growing improved types in other crops, the output of the country has been perceptibly increased. Persons who do not believe that much benefit has occurred from plant breeding work often compare the standard yields of crops per acre as published in the crop statistics of India with those of other countries to support their case. In the case of rice crop, for instance, the average acre yield in India, which is 825 lbs. in 1937-38, is about one-third to one-fifth of yields obtained in Spain, Italy and Japan. Similarly, the average acre yield of cotton crop in India is 89 lbs. of lint as compared to 267 lbs. and 531 lbs. respectively in America and Egypt. It is hardly realized, however, that India is a big continent with very divergent climatic conditions and rainfall as compared to countries which register high yields and the total area under the crop in these countries is comparatively small. It will be hardly legitimate to make such a general comparison between countries. So far as can be seen from the published records and from personal knowledge of some important plant breeding centres in the West, the actual increase in *yield* as a result of plant breeding is generally never higher than 20 per cent. This is the figure that has been declared as a workable limit for rice breeding in Japan. If Indian acre yields are still low, the reasons have to be sought elsewhere. India is an old country and manuring is never practised. The increased yields of strains are marked by the comparatively smaller areas devoted to them. In regions where strains are grown on a larger scale, protected by irrigation and sometimes fertilized, very much larger acre yields are recorded, as for example. Co. 2 cotton tract of Coimbatore and deltaic rice tracts of Madras. In Egypt, cotton yields are high due to irrigation, heavy manuring and silty soils and in America to manuring, virgin soils and protection against erosion. In certain rice areas of Madras where suitable conditions exist, it has been possible to demonstrate that by the growing of improved strains combined with intensive methods of culture, the acre yields can be increased to 3,000—4,000 lbs. per acre, comparable to yields obtained in Japan. I am confident that plant breeding work in India, both from the standard of work and the results achieved, is quite comparable to similar work done in more advanced countries of the West or East.

iii. *Need for improved agricultural statistics.* In this connection it may be useful to raise the question of the average yields of crops as published in crop statistics. What is the basis of these figures? It is only recently that this question is being examined. Even in the case of cotton where, due to the cotton cess, it is possible to estimate fairly accurately the total output of the country, the figure arrived at by this method differs from the figure given in the statistical reports by over 30 per cent. In the case of other crops, some tests made in isolated centres have shown that the figures vary from those of the statistical reports very considerably. Even the recording of the area under any particular crop has been found to be inaccurate. So far as can be ascertained, the figures of the statistical reports are not of much value. It is a good thing that the Imperial Council of Agricultural Research have taken up the problem of determining standard yields in wheat and rice. A similar investigation is being started for cotton also. Granting that the production is certainly higher than what is stated to be, such increased production should be reflected in a greater well-being of the cultivator, and the question may be asked whether there is any indication to that effect. There is, however, one thing to be mentioned in this connection, namely, that the population of the country has also considerably increased and there are probably other considerations which may be pertinent though beyond the scope of this discussion.

III. Methods of Breeding.

The principles and technique of plant breeding may be briefly described here. Of the three methods mentioned earlier, namely, selection, introduction and hybridization, introduction may probably be left out though there are instances, almost historical, on record, of introduced superior types from one region to another proving a phenomenal success. Such successes are more an exception than a rule, since it is within the experience of plant breeders that the great range of agricultural and climatic conditions under which a particular crop is grown in different parts of the country has resulted in special local adaptations which naturally limit the scope of such introductions. We can consider the other two methods in greater detail.

i. *Selection in natural population.* In the tropics, the plant material has not received the intensive study which has been applied to the temperate crops before the ideas of pure lines and Mendelism were brought to bear on the problem. Every crop presents a mixture of types. Sometimes there may be a dominance of one particular type which may amount almost to a condition of purity, but there is enough evidence that such approximation to purity has risen by the suppression of other types by natural agency. The type best adapted to the prevailing conditions survived, but where adaptation for more than one type is sufficiently close, a mixture of types forms the crop. Selection in such material is nothing but exploitation of the naturally existing variability. Have we any methods to say which primary selections in the variable material would give the desired result? The answer to such a question is, so far as we know, No, and this is the main reason for considering plant breeding as more an art than a science. Intimate familiarity with the crop and the scale on which the selections are made and studied are often the deciding factors in the attainment of success in the method. There is no known method of discriminating the important environmental influence on the crop and the testing of the progenies in replicated and randomized plots is the only criterion to go by. The larger the number of initial selections handled, the greater are the chances of getting a useful type, and for the elimination of undesirable types at the initial stages, the breeder has still to depend upon his visual observations Although due to the recent advances in statistics as applied to agriculture, designs have been evolved to test even a very large number of initial selections in a replicated experiment, (the incomplete randomized blocks and modifications of the design), still, elimination of a certain number of initial selections without actually bringing them under replicated trials cannot be avoided. Usually the initial yield trials carried out by the plant breeder in smaller plots are later extended to trials in bigger plots under cultivators' conditions in various parts of the tract and the best selection as determined by these series of trials is multiplied and made available for distribution to the cultivators. It has been the experience of the more successful plant breeders that it is not necessary to wait for commencing the district trials until the small scale trials are actually finished, but to carry on the two trials simultaneously in the later stages. Thanks to the work of the statisticians, the technique of carrying out the trials has been very much simplified and reduced to a routine. This is in brief the method followed in the selection technique in cereals, rice, wheat, *jowar*, etc. These crops are almost entirely self-fertilized and the initial selection is itself assumed to result in isolating several pure lines and all further work is directed towards determining the best among the several pure lines.

When once pure lines have been established, secondary selection is not usually practised in these crops. It was once tried in rice in Coimbatore to see if there was still genetic variability in one of the established pure lines. Yield was the only criterion that was taken into consideration as there was no morphological variability in the material. Since the variations in yield observed were within the limits of experimental error, it was concluded that it was not worth making secondary selections in this crop. There are not many records of systematic secondary selection being practised in the cereals and even the few cases mentioned have been carried out more from the point of view of characters than of yield. In cotton on the other hand, secondary selection has always been practised by breeders though, as has been pointed out by Mason (1938), the effect of such secondary selection has been in most cases only of a small advantage while the main improvement has been realized in the primary selection. Such secondary selection has been, until very recently, mainly towards making the selection homozygous, i. e. reducing the genetic variability. In cereals, while once a selection is morphologically pure and also reasonably pure for economic characters like duration, height of plant, size of grain, etc., the only point for consideration was yield. In the case of cotton, however, though yield continues to be the main consideration, attention is devoted to two other important characters, namely, length of the fibre and the ginning percentage. These two quantitative characters, to be mentioned again later, are controlled by a number of Mendelian factors and it is impossible to get absolute homozygosis for these characters even after several generations of selfing. Secondary selection has been mainly directed to reduce the heterozygosity in these two characters to the minimum, and carry forward such of these selections as are apparently pure.

It will be seen from the above that the main principle of selection, namely, exploitation of the naturally existing genetic variability, is not lost sight of in the case of making secondary selection. Hutchinson and Panse (1937*b*) have found out that environmental effects contribute so much to the variability of the breeding material that genetic effects remain undetected by the usual method of progeny-row method and have improved the technique enabling comparison to be made of genetic effects freed from environmental disturbances. The principle of secondary selection is based on the existence of genetical variability, and the attempt of the plant breeder should be to obtain a progressive improvement in his material by the isolation of superior types arising by segregation in the progeny of initially heterozygous selections The new replicated progeny-row technique developed by them helps the breeder to divide the best of his material into two lots, one in which further selection is likely to be profitable, and that which has reached the limit and may be passed on from the breeding to the testing plots. The technique has been used successfully in cotton breeding in Indore and a type with a better quality has been evolved from strain that was considered under the previously known methods of breeding to be already fixed for that character. In addition to improvements in yield, this technique has also proved highly useful in developing cotton selections showing high field resistance to the *fusarium* wilt. From material which showed a mean field mortality of 60 per cent, due to wilt, strains have been obtained with less than 10 per cent. mortality.

While the value of this improved technique has been definitely demonstrated in the case of cotton, the question remains whether it would be worth applying it to other crops, particularly, the self-fertilized cereals. An attempt was made to use the method in the selection experiments going on at the Indore Institute on *jowar* and linseed. The data so far available have definitely shown that, while there was no sign of progressive improvement in yield by such secondary selection, genetic variability in lodging of straw in *jowar* and in resistance to wilt in linseed was demonstrated.

ii. *Selection in hybrid population.* We then come to the question of plant breeding by hybridization. When we find that simple selection is not yielding any material of value, it means that there is no genetic variability to select from, and the only recourse left is to resort to hybridization between varieties so that genetic variability would have been produced to give scope for selection again. Although plant breeders did carry on crossing among varieties even in earlier days, the scientific background for the work was provided by the re-discovery of Mendel's Laws in 1900 and which is now a highly developed science under the name of Genetics. Mendelian principles of heredity are so well known that I need not deal with them here. The science of Genetics has been of great value to the plant breeder in that it has given him a clearer conception of his problems and a better understanding of the process involved in his work. When Mendelism was first brought to light, great hopes were entertained of combining into one plant various attributes coming from different parents. Whether the practical results obtained in economic plant breeding since the advent of Mendelism have been commensurate with these hopes, there are differences of opinion. The main aim of economic plant breeding is to get greater yields. Using this as the criterion, it is probably a safe assertion to make that the influence of the science of genetics has been much less profound on the art of plant breeding than was expected by the early genetics. There is, however, one aspect of the genetical knowledge which has produced profound results.

The knowledge that physiological characters like resistance to diseases, cold, etc., are also inherited in the same way as other characters have led to the classical triumphs of Prof. Biffen in producing rust resistant wheats and of Prof. Nilsson-Ehle in producing winter resistant wheats and barleys. Even in India this aspect of plant breeding plays an important part and conspicuous successes have been obtained. We need mention only as examples the wilt resistant *arhar* of Pusa, wilt resistant cotton of Bombay, and blast resistant rice of Madras.

A reference to the annual reports of the Provincial and Imperial Departments of Agriculture in India would give an idea of the number of improved types that have been evolved by plant breeding and it is not necessary to give a list of them here. It may, however, be worth mentioning some of the most outstanding ones which are now under cultivation very extensively.

Selections in natural populations:—

Rice	...	GEB. 24 of Madras.
		Indrasail of Bengal.
Wheat	...	Number 4 and 12 of Pusa.
		8A of the Punjab.
Cotton	...	Co. 2 of Madras.
		V. 434 of Central Provinces.
		P. 289F of the Punjab.
		Sind Sudhar of Sind.

Selections in hybrid populations:—

Wheat	...	Pusa 52.
		C. 518 and C. 591 of the Punjab.
Cotton	...	1027 A. L. F. and Jayawant of Bombay.
Sugarcane	...	Several Coimbatore types like Co. 213, Co. 281, Co. 290, and Co. 419.

iii. *Mixture or Pure strains.* The question of the utility of growing a mixture of types rather than a single type may be considered. The idea might appear unscientific to persons accustomed to orthodox views of pure lines, homozygosity, etc. Still it will be evident from what follows that the problem deserves consideration. There has been experimental evidence available with plant breeders to show that a mixture of types grown as such, gives a greater yield than the components of the mixture. Simple isolations of pure types have no doubt proved an improvement over the local mixtures in several crops like rice, cotton, *jowar*, etc., though it is a general experience with plant breeders that such improved types are of limited value beyond the narrow range of conditions obtaining in small tracts where they were isolated. It is more reasonable to assume perhaps that a mixture of types should prove of greater utility over a wider range of conditions. That certain components of a mixture in spite of their poor performance when grown pure, do manage to maintain themselves in a fairly constant proportion from season to season can only be explained by the advantage they get when grown in competition with other types. The Upland cotton of Central India, when grown as a pure rain-fed crop, suffers badly from diseases and is a poor performer but gains in competition when grown mixed with the indigenous cotton. There have been experiments going on for the last five years with growing these two cottons under different degrees of competition and while the results as regards yields are variable there is a definite indication that the Upland cotton gains by competition effects from the indigenous. There was, however, one consistent result obtained in all the years, namely, that the American in the mixed crop suffered less from leaf-roll and red-leaf than as a pure crop. There was also an indication of the indigenous cotton suffering less from wilt (*fusarium*) in mixed crop.

It might be worth mentioning here that there is experimental evidence to show that mixtures do contribute to better spinning quality. For the last two seasons, the material from the experiments with mixtures at Indore has been examined by the Director of the Technological Laboratory, Bombay, and as the figures given below would show, the mixture has a higher spinning value than the average of the two constituents sometimes even approaching the value of the better of the two constituents.

Spinning values (highest standard Warp Counts).

Mixtures.	1937–38			1938–39		
	Actual.	Average of constituents.	Difference.	Actual.	Average of constituents.	Difference.
M9* + M.43.4 ...	22	19·75	+2·25	16·5	17·25	−0·75
M9 + V.434 ...	25	22·50	+2·50	21·0	19·50	+1·50
M9 + M.U.4 ...	20·5	19·0	+1·50	24·0	22·50	+1·50

* M9 ... An arboreum strain evolved at Indore.
M. 43 4 ... Another arboreum strain under study at Indore.
M.U.4 ... An Upland cotton strain under study at Indore.

That fairly consistent results are obtained over two seasons and that similar results have also been obtained at the experimental mill, Egypt, (Hutchinson, 1938*b*) show that the mixtures are in no way a disadvantage from the spinning point of view. Even granting that the growing of mixtures is proved to be more profitable to the cultivator, there are several practical difficulties in giving effect to the findings, but still such difficulties should not preclude the breeder from examining the question.

IV. Development of Genetical Science.

i. *General.* In the early years of genetics, all attention was concentrated on crossing two types, observing the ratios in which any particular character or characters were appearing in the F_2, and deciding that the character or characters were controlled by a single factor, two factors, complementary factors, duplicate factors, etc. Any inheritance phenomenon of a complicated nature was usually ascribed to multiple factors and laid aside. The results all tended to nothing beyond the confirmation of the universal applicability of original Mendelian laws and their later extensions. The second phase of the development of the science of genetics was the study of the chromosomes and the unassailable evidence produced that they are the carriers of hereditary units or genes. All genetic evidence accumulated so far indicates that the gene offers an efficient mechanism for the evolutionary progress of living organism. Studies on the morphology of chromosomes and the irregularities in their behaviour have been used to determine linkage groups and changes in the inheritance of characters and their linkage relationship. There are some aspects of cytological research which are of great interest and importance to particular breeding problems, as for example, the chromosomal interpretation of species relationship, the conception of polyploidy and the explanation of sterility and peculiar forms of inheritance. Breeding programmes involving wide crosses between species or even genera are based upon the results of cytological research. The use of physical agents like X-rays, radiation, heat, cold, etc., has been brought into play to produce by artificial means changes and disruptions in the composition of chromosomes producing mutations more abundantly and at a quicker rate than what were occurring in nature. More recently alkaloids like colchicine have been used to double the chromosome complement of an organism and thus make a sterile hybrid fertile. The advances in these branches of science, genetics and cytology, have no doubt had their effect on plant breeding. Hudson (1937) in his excellent review has brought together the cases where such advances have been made use of. The advances in the two branches which had remained entirely distinct through much of their developmental history are all converging to a common synthesis and understanding. One going through the literature on genetics that is appearing in recent times, will be really stunned at the progress that has been made. This progress, however, has not been of help to evolve plant breeding methods, but the plant breeder has still to keep abreast of the advances in genetics and cytology and try to incorporate the precepts in his own work so that he can have a greater control over his material.

In the field of breeding horticultural and vegetatively propagated crops the value of new genetical and cytological technique is appreciated and in attacking breeding problems full use is made of the latest advances in those branches. The recent work on potatoes may be mentioned in this connection. The only agricultural crop, where an effective collaboration between geneticists and plant breeders has resulted in results of practical value, is maize in America. It is in the breeding of self-fertilized crops that the value of such advances has not become as apparent as one would wish it to be.

ii. *Genetical work in India.* The actual position of the work in India in the light of the advances mentioned above may now be considered. Although actual plant breeding has produced tangible results of economic value, probably even more tangible than one would expect from the time and money spent on it, it must be admitted that the latest advances in genetical science have had no appreciable effect on this output. It was mentioned earlier that the first phase of genetical science was the phenomenon of segregation. If we look into the published papers in India within the last 25 years (1910—1935), there have been over 200 publications dealing with the inheritance of characters in crop plants. A large majority of them deal with the simple question of Mendelian ratios. It is only a few that might be considered to go beyond the question of simple ratios. It is known, however, that characters like yield itself and those that contribute to it, as for instance, the number and size of the ear in cereals like rice and wheat, and ginning percentage and lint length in cotton, to mention only a few, are quantitative in their inheritance and controlled by numerous genes each probably having a small effect and impossible to distinguish in the later generations of a cross. Genetical analyses on these characters are hard to follow because of their complex inheritance. Recognition of genotypes which is essential for the usual genetic analysis is generally very difficult as they cannot be separated from environmental fluctuations. Eye judgment in many cases are quite inadequate and simple empirical tests are not always available for isolating all genetic variants. The inheritance studies on such quantitative characters have therefore not received as much attention as they deserve.

The actual genetical contributions in India are from those who are practical plant breeders, and crop botanists working in the departments of agriculture, Provincial and Imperial. Their work is circumscribed by the immediate and pressing need of producing an improved strain of a crop, the introduction of which would bring a greater return to the cultivator. The material they set to work upon was the crop grown in the cultivators' fields which was an untouched and richly variable population, and simple selection had given very encouraging results. Almost all the improved strains that have been given out to the cultivators are such simple isolations. By the very nature of the material dealt with, and due to local adaptations, the strains so evolved with rare exceptions, as for example, GEB. 24 rice and Co. 2 cotton of Madras, are necessarily limited in their usefulness to the particular areas in which they were isolated. This naturally led to the decentralization of plant breeding research, which was originally confined to a central station in each Province, and a number of small breeding stations, one in each of the important tracts of the crop, were opened where the crop of that locality could be studied. This is the experience in Provinces where plant breeding work has been going on for a longer time, as could be seen from the number of rice breeding stations in Madras and the number of cotton breeding stations in Bombay and Madras.

The earlier hybridization work that had been undertaken was intended to combine in one individual valuable attributes from one or more types and though the breeders did have a clear idea of what combination they wanted to achieve, the knowledge about the inheritance of the characters, they wanted to combine, was, however, lacking. Such hybridization programme was more or less a hit and miss method and if any success had been obtained, it was more an accident. The crosses were, however, useful for studying the inheritance of some of the easily distinguishable qualitative characters and most of the publications deal with such inheritance. This is practically the position, at any rate, with some of our most important crops like rice, cotton and wheat. In millets, where selection and genetical studies have been of a more recent date, almost all the publications deal with such Mendelian ratios and breeding for special yield attributes is still in its infancy.

Selection work, whether from a naturally variable material or from hybrid populations, was probably considered a mere routine which anyone with elementary knowledge of genetics could undertake. This might be true to some extent because of the nature of material one is dealing with in a country like India. That still greater achievements in plant breeding have not been recorded in India, might be attributed to the fact that the nature of the material available to the breeder was not correctly understood and too much emphasis was laid on purity of character, morphological and economical. It is desirable for a plant breeder to have a sound knowledge of the advances in genetics and cytology though he may not yet be in a position to utilize all such knowledge in his everyday work. That more tangible results have been obtained in some Provinces than in others might be partly attributed to the fact that breeding work was carried on side by side with genetical studies and also perhaps to better technique employed.

V. Genetics in Relation to Plant Breeding.

i. *Quantitative inheritance.* The advance in genetics as applied to the quantitative characters and what influence this is likely to have in plant breeding technique is dealt with here. It is true that new conceptions of multiple factors, quantitative inheritance, transgressive segregation, factor combination and inhibition have been invoked, but these have helped but little in practical plant breeding. The study of the inheritance of quantitative characters is intimately associated with applied mathematics and it is this that has practically scared away earlier geneticists and plant breeders from undertaking such studies. The application of statistical methods to living things is known as biometry and has developed into an important branch of biological investigations. Biometry is a necessary mathematical tool for dealing with the inheritance of quantitative characters and no modern geneticist can make much progress without a good grasp of this branch. As was pointed out in an earlier section, the variations on which breeder has to work are of two kinds, environmental and genetic, and it s only when the latter component forms a substantial portion of the total variance, selection can be effective and the problem he has always to face is to reduce the environmental variance to the minimum by suitable technique. In the case of hybrid progenies, the classical method of selfing and selecting from F_2, F_3 and so on, has been the chief method followed and has proved successful in cereals, wheat, rice and also in cotton. As practical examples of successes in this line are rice strains evolved combining yield and strength of straw, yield and resistance to paddy blast, and yield and shorter duration, etc., in Madras. Similarly, the case of strains evolved recently by the Cotton Specialist, Coimbatore, combining yield and fine and long lint in Cambodia cotton may be mentioned. But such achievements have been brought about not with the definite knowledge of the inheritance of the particular characters whose combinations have formed the end in view. Can the geneticist suggest more rational methods of what to select and how to select in the hybrid progenies and give information on the genetic variance involved in the different generations starting from the F_2? A beginning has been made at Indore to answer these questions with regard to cotton and I should refer to the work of Dr. V. G. Panse who has just published the first results of this study (1930*a*, 1940*b*). Because of the special statistical methods involved, the work was carried out with the suggestions and guidance of Prof. R. A. Fisher. The quantitative character studied was lint length which is one of the important and at the same time complex characters in cotton, in crosses among *G. arboreum* types.

He has shown from theoretical considerations that the genetic portion of the variance in a population can be estimated by growing a set of progenies from individuals belonging to that population and taking the regression of progeny means on parental values. This is an important result, for, as has been stated before, the capacity of a population to show immediate response to selection depends on its genetic variability. The genetic variance in the F_2 population of crosses between C. 520, Malvi and Bani was estimated and is shown below:—

Cross.		Total variance in F_2.	Genetic variance.	Non-genetic variance.
C.520 × Bani	...	3·015	1·543	1·472
C.520 × Malvi	...	3·273	1·576	1·697
Malvi × Bani	...	2·416	0·375	2·041

In the first two crosses, nearly half of the variance is genetic, but in the third cross it is only fifteen per cent. of the total variance While the bulk of the non-genetic variation would be environmental, the presence of dominance and other interactions between factors would also contribute to it. The effect of non-genetic variability, whatever its source, would be to retard the progress made by selection.

In populations with the same amount of genetic variability the degree of improvement achieved by primary selection will also be the same but the response to secondary and later selections will be determined by the genetic constitution of the character, namely, the magnitude and number of factors involved and their dominance and epistatic relations. With only a small number of factors, the possibility of further improvement by selection will soon be exhausted, whereas with a larger number, selection can be continued profitably much longer. As the variation is continuous and the individual genotypes cannot be recognized, unlike in simple qualitative characters, only a statistical approach is available to study these questions. It does not mean, however, that the estimation of genetical variance and the number of Mendelian factors involved will straightaway solve the difficulties of the breeder, but if genetics is to play its part in the art of plant breeding such studies are essential.

ii. *Heterosis.* It is within the experience of every plant breeder that the first generation hybrid is more vigorous than the parents and such vigour disappears gradually in successive generations, and it is to this phenomenon that the term heterosis has been used. We need not go into the theory of heterosis, but it is enough to state that the problem of heterosis is the problem of the inheritance of quantitative characters. The heterosis effect has been demonstrated in crops with regard to several economic characters and the greater the gap in the relationship between the parents crossed, the greater the expression of heterosis. Can the plant breeder make use of the heterosis in his work? In vegetatively reproduced crops like sugarcane and potato, when once the cross has been made, the vigour associated with the hybrid can be maintained almost indefinitely. In cases where hybrid seeds can every time be produced in sufficient quantities to raise a field crop, the phenomenon is of benefit even in crops with sexual reproduction. This has been possible in maize and the advance in maize breeding in U. S. A is nothing but the exploitation of this principle. Hybrid maize is the most outstanding example of the influence of theoretical scientific research in revolutionising the production practices of an agricultural crop. The same principle is being applied recently to breeding sugar-beet crop in Sweden. The only grain crop of India in which the breeding principles applied to maize, can be used is *bajra* (*Pennisetum typhoides*), but no serious breeding work has yet been taken up in this. In breeding self-fertilized crops on the other hand the expression of heterosis in any considerable magnitude is bound to arrest progress in selection. In the example of the cotton cross discussed in the previous paragraph, the portion shown as non-genetic variance would include the effect of heterosis. It must be stated in this connection, that it is so difficult to analyze the non-genetic variance apart from the fraction due to environmental effect into components due to dominance, heterosis, epistacy, etc., as they are all interrelated to each other.

iii. *Physiological and Genetic Correlations.* Another aspect of genetics in which more critical research should prove useful to the plant breeder, is with reference to characters that show physiological or genetic correlations. It must be within the experience of every plant breeder that selection for improvement on a particular character results in improvement only up to a point. Beyond that, gains are compensated by depreciation in other characters. There is evidence of several physiological correlations in crop plants like cotton, rice, and wheat. In developmental studies with cereals like rice and *jowar* in India, the correlation between yield and other characters like size of ear, height of plant, tillers, etc., have been extensively studied and recorded. To discuss a few of these in rice, the height of the plant is very highly correlated to duration (Ramiah, 1933) so that as a general phenomenon, late duration varieties are likely to be taller than short duration ones. Naturally this would set a limitation to obtaining a very short stature type with a long growing period and *vice versa* though there is likely to be a wide margin for variability in height or duration within the two groups considered separately. Similarly, a correlation is found to exist between yield and duration in the rice crop which may vary anything from 3 to 8 months. Generally under South Indian conditions the best yielders are those that have a medium duration of say, 5 to 5½ months. Though varieties of shorter duration, 3 to 4 months, are sometimes found to give high yields of 3,000 to 4,000 lbs. of grain per acre under particular conditions of soil and climate, they are generally not so heavy yielding as the later duration types. Varieties of over 6 months in duration, which people are obliged to grow because of certain special conditions in a particular tract, are generally also not very heavy yielders. That this relation is physiological can be seen from the series of experiments that have been conducted with them in Madras (Ramiah, 1937). Since these long-duration varieties are generally season limited, any reduction in age beyond a certain minimum brought about by unseasonal planting reduces their yield potentiality. Now the question is whether a very high yield associated with a variety of, say, 5 months' duration can be combined with an early duration of 3 months. Experience in Madras would appear to show that breeding for such an end in view should prove a waste of time and effort. There was an interesting case in rice where an attempt to combine a packed arrangement of the spikelet on the panicle with a medium size of the grain ended in failure (Ramiah, 1931*b*). The close packed arrangement was always associated with a small grain. The correlation here may be either physiological or simply structural. The case of the cross in rice to combine panicle length and clustering of spikelets may also be mentioned. Combination of length in the panicle with the clustering of the spikelets proved impossible (Ramiah, 1931*b*, l. c.).

There are more chances of the breeder achieving his end, if the character combinations he is after, are genetic rather than physiological. In the case of cotton, within *G. arboreum* species there are types with very high ginning percentage, but with lint of very poor quality, and types with poor ginning but with finer and longer fibre. The cotton breeder would like to combine these two characters as high ginning and longer fibre as both contribute to a better price being obtained by the cultivator for his produce. Though critical evidence is lacking, it may be stated from the results of breeding data available, that it is not possible to combine the two characters beyond a certain limit. To get critical data bearing on the point, an experiment has been going on for the last three years in Indore which may be referred to here. In the F_2 population of the crosses between C. 520, Malvi and Bani, plants with the highest and lowest values of ginning percentage and with the highest and lowest values of lint length were selected and F_3 progenies grown from these. The correlation coefficients between the mean values of the progenies for ginning percentages and lint length are:—

C. 520 × Bani	...	– 0·254
C. 520 × Malvi	...	– 0·425
Bani × Malvi	...	– 0·286

All the three coefficients are negative but insignificant. The combined correlation coefficient is – 0·324, which just falls short of significance on the 5 per cent level. This small negative relation between ginning percentage and lint length is reflected in progenies selected for high ginning percentages having a slightly lower lint length than those selected for low ginning. It is probable that this negative association is genetic rather than physiological, because no such consistent relationship is observed between the ginning percentage and lint length of the individual parental plants of these progenies. The fact that the processes of lengthening and thickening of the cotton fibre do not take place simultaneously also supports the conclusion that the relationship is not likely to be physiological.

Cases of several correlations between morphological and quantitative characters have been recorded in cotton and rice and to have an idea of the scope of such correlations the following few may be mentioned here:—

Cotton:—between corolla colour and lint length; between corolla colour and lint index (Hutchinson, 1931); between red plant body and length of vegetative period (Leake, 1914), and lint colour and lint length (Kottur, 1923).

Rice:—between sterility and growing period (Ramiah, 1931*a*); between anthocyanin pigment and yield (Ramiah, 1933 l. c.); between anthocyanin pigment and tillering (Ramiah, 1935) and between colour of grain and weight of grain (Parnell *et al.*, 1922).

Such studies in other crops should prove very useful to the plant breeder.

iv. *Use of 'Discriminant function'.* In very recent times the question of the use of 'discriminant function', first suggested by R. A. Fisher (1937) in plant breeding has been brought i . The only paper we have relating to the subject is that of Fairfield Smith (1937) which relates to wheat and he comes to the conclusion that with a number of lines derived from a 'composite hybrid mixture', initial field selection for yield might be made on the basis of the size of the grain. In simple language the principle may be explained as below. In every crop the yield could be divided into a whole set of different features as for example, the number of ears, the number of grains per ear and the weight of the individual grain in cereals like rice and wheat. The analysis of yield might show that certain of these attributes are more variable due to environmental conditions than others, and in basing selections for yield, more weight should be given to such an attribute that shows less variability due to environment. The principle is perhaps not new as the developmental studies initiated by Prof. Engledow in Cambridge did take into consideration the yield attributes in making selections, but no systematic experiment has been made on the points. In rice breeding also such attributes of yield as tillering, ear size and grain size have been used successfully. A necessary requirement for the use of a discriminant function is experimental data to determine what measurements are least affected by environmental fluctuation. In cotton for instance, there are several characters which are components of yield such as bolls per plant, seed cotton per boll, seeds per boll and lint per seed. Though from experience it may be stated that some of the above attributes like bolls per plant were much more variable than others, an attempt is being made in Indore to get experimental data to see how far we can use the 'discriminant function' in cotton breeding.

v. *Wide Crosses.* The problem of the wide crosses and study of the range of variability in crop varieties may be considered at this stage. This has come to the forefront because of the work of Vavilov and other Russian botanists and because of the great advance made recently in the study of polyploidy. One often hears of the necessity to have a wide collection of types for use in breeding. So far as India is concerned, the point has got its possibilities as well as its limitations. For instance in cotton, India being itself the home of one of the most important species *G. arboreum*, with several secondary centres of origin (Hutchinson and Ghose, 1937*a*), there is nothing probably to be gained by bringing in new collections from outside so far as this species is concerned. But the demand for producing better quality cottons in India is sometimes considered capable of solution by the increase in the cultivation of Cambodia or Upland cotton (Ramanathan, 1938). All the types of this cotton that are now being grown extensively are the relics or acclimatized types of Upland Americans introduced from America in earlier years. Selection from the introduced types of America has not been very fruitful. No material from the original source with plenty of genetic variability has been tried and it is possible that in its original home types may be available that may prove suitable to tracts in India which do not grow this cotton now. It is from this point of view that an extensive collection of material from the original source might prove of interest. Similarly, intensive attempts by breeders to improve *G. herbaceum* cottons of India have led to the same inference that material from outside India should be introduced (Ramanathan, 1936).

With regard to rice, there is plenty of variability to be found in the various parts of India and there appears to be no justification for introducing variable material from outside. There are still several unexplored regions within India itself and work in Coimbatore has shown that such exploration is bound to give the breeders new species, still undetermined, which may be usual to them. The importance of wide crosses particularly with wild types is receiving increasing attention and the results of such work elsewhere and in India too have been useful in introducing into the cultivated types, characters such as hardiness and resistance to diseases which are usually present in wild forms. From this point of view, collection of wild types is certainly desirable and it has proved of practical importance in sugarcane already. Similar results are expected in potato also. Exploration of wild types particularly in the improvement of fruit has not received any attention it deserves in India, though North East India is known to be the original home of certain citrus types.

Though there has not been much of genetical work as related to wide crosses in India itself, workers in India have not failed to make use of the knowledge accumulated elsewhere in attempting wide crosses. More from the scientific point of view, some years ago a programme of crosses between different species of rice was undertaken in Coimbatore. Some of them had proved of cytological interest and in throwing light on the phylogeny of rice (Ramanujam, 1938), (Parthasarathy, 1939). It is interesting to note that the progenies of one inter-species cross *O. sativa* × *O. longistaminata* has given some material of economic value. In one of the papers contributed to the agricultural section of this year (Sreenivasan *et al*, 1941) is recorded the obtaining of drought resistant strains from the above cross. It is quite likely other interspecies crosses might also give useful breeding material.

Regarding interspecies crosses in cotton though crosses within the Asiatic species and within the New World species are practicable and have been extensively tried, there is no record to show of any valuable material having been obtained from such crosses. Harland's work (1932) has shown that crosses can be effected between the two Asiatic species and between the two New World species, but homologous characters are built up in such widely different ways in them that the genetic balance is usually disintegrated by segregation in F_2 and later generations. He has, however, shown (1936) that it was possible to transfer single genes or small groups of genes from one species to the complement of the other, but not breeding of intermediate types. This is achieved by the technique of repeated back crossing and one of the recent cases where a success has been reported (Knight and Clouston, 1939), is a cross between *G. hirsutum* × *G barbadense* where the resistance to 'blackarm' in one of the strains of the former has been transferred to a type of the latter using the above technique The crosses between the Asiatic and American species are still wider since they involve differences in chromosome number as well. But even such wider crosses have not scared away plant breeders and have been made in Russia and recently in India as well (Amin, 1940). The knowledge about the use colchicine in doubling chromosomes has encouraged these attempts and since the work is still in an experimental stage, nothing can be stated definitely about its economic possibilities.

In fact, the lead in the attempt at wide crosses has come from India particularly in sugarcane, due to the enterprise of Rao Bahadur Venkatraman. He has succeeded in making such wide crosses as between sugarcane and sorghum and more recently even between sugarcane and bamboo. The latter work, though still in its infancy, appears to show enormous possibilities of improving the sugarcane crop. It must be remembered, however, that sugarcane is a vegetatively propagated crop and the difficulties of further selection are absent.

In rice where all the cultivated forms are grouped under one single species with the same chromosome number, there are geographical races which differ in their chromosome make up. Crosses among such races are possible and have been repeatedly made in spite of initial difficulties in several cases, but still there is no record of any considerable practical success having been obtained by such crosses anywhere. The case is, however, different in cotton where different races of *G. arboreum* and *G. herbaceum* exist with the same chromosome numbers and hybridization among them within the species has given results of practical value.

vi. *Limitations in wide crosses.* With our present assumption of a large number of genes controlling quantitative characters, one should expect to get all possible combinations of characters in the F_2 and later generations provided, a sufficiently big population is grown of them. Recent work by E. Anderson (1939 *a* and *b*) on the point is very illuminating. He has shown by experimental data in a species cross in tobacco that, however manifold the recombinations might seem, they are in reality but a small proportion of the possible recombinations of the parental species. He discusses the powerful restrictions to character recombination in F_2 under four heads: gametic elimination, zygotic elimination, pleiotropy and linkage. Every plant breeder must be quite familiar with gametic and zygotic eliminations in crosses between species or races which manifest themselves by pollen sterility and non-viability of seed produced. The question of pleiotropy where a single primary effect of a gene results in manifold effects on the development of the plant has not received as much attention as it probably deserves. Recently we have been studying in Indore the pleiotropic effects of one of the genes that is responsible for lintlessness in cotton. The homozygous lintless type is a much shorter plant with suppressed internodes, somewhat late in maturity and with a definitely different growth rate as compared to the linted type. The lintless type has also shown variations in its survival according to the environmental conditions. The large number of genes controlling quantitative characters located in the various chromosomes should, as shown by Anderson, be closely linked because of the restricted number of crossovers possible in the chromosome. It is definitely proved that in spite of variations from plant to plant in the hybrids as a group, the characters of the parental species or races tend very strongly to stay together. The above findings have an important bearing on plant improvement. In this connection mention might be made of a serious effort made in Coimbatore over a series of years to obtain a valuable combination of characters found in different races of rice. One of the types originally imported from Java had a special characteristic of very long ears, about twice the length of any to be found in the local types, but the length was compensated in this variety by extremely poor tillering, i. e., fewer heads per plant. The attempt made was to combine the ear length of this variety with a greater number of smaller ears in another standard strain. The cross was carried on up to F_9 and F_{10} selecting from each generation in the usual way and ultimately when the final selections were compared against the local strain, they failed to approach the yield of the latter. It is known that tillering and ear length must be controlled by several factors and the failure of the attempt to synthesize this desirable combination only shows that such a combination, high ear number of one parent with the length of the ear of the other parent did not occur in the cross. We should probably have been content in this cross with an intermediate tillering and intermediate size of ear. As Anderson has pointed out the most efficient way of achieving the desirable combination would have been to make crosses among selections which are most like one of the parents in ear length with those which are most like the other parent in ear number. In this connection another interesting cross in rice which has been attempted in the United Provinces might be mentioned (Sethi *et al.*, 1937). The problem of rice fly infestation is important in this tract and trials are being made to get over the difficulty by producing types with enclosed earheads by crossing the ordinary type with another *sathi* type, where the earhead remains enclosed inside the leaf-sheath (cleistogamous). The *sathi* rice is a very poor yielder and has a coarser grain, but cultivators grow it for this one character of its escaping the attack of ear fly. The cross has been carried up to F_6 or F_9 generation and types with enclosed ears have been obtained which are an improvement over the *sathi* rice, but not comparable to the normal type in yield. The inheritance of the enclosed ear type has been studied and found to be of the multiple factor type and it is quite possible greater progress might be achieved by crossings among selected types, those *approaching* the *sathi* parent in ear character and those *approaching* the normal type in yield from the hybrid generations. This is probably a definite case where advances in genetical knowledge could be put to practical test in economic plant breeding.

VI. Maintenance of Purity of Strains.

The question of the deterioration of strains once fixed and released for distribution to the cultivators might be considered. It is a usual complaint from cultivators that a strain, though known to give a good performance to begin with deteriorates after a period of time. Such deterioration where it is proved to exist may be either due to non-genetic or genetic causes. In spite of the fact that sugarcane is a vegetatively propagated crop, the deterioration of the Coimbatore types intensively cultivated in the United Provinces can, from the data available so far, be shown to be due to greater incidence of pests and diseases because of the faulty agricultural practices, namely, the growing of the crop repeatedly without sufficient rotation in exhausted soils. In the case of self-fertilized cereals like rice and wheat, so far as simple (selections) pure lines distributed by the Departments are concerned, there is no evidence of such deterioration. Once, seed of a strain of rice (GEB. 24) in Madras was obtained from the district where it had been distributed four years previously and in an experiment at the central station no sign of deterioration could be found. It must be pointed out, however, that the seed was to all practical purposes as pure as the seed of the experimental station itself. A similar result was obtained in Coimbatore with regard to Co. 2 cotton strain (Ramanathan, 1937). Dr. Shaw (1935) mentions a case where one of the Pusa strains of wheat had been declared to have deteriorated, but he found the seed obtained from the locality to have been badly mixed up with other types. Fairfield Smith (1938) has mentioned a case in America where some of the wheat strains from Turkey Red Wheat which were very much better than the control to begin with ultimately came down to the level of the control after some years. While deterioration due to the strain getting mixed up with other inferior strains in the course of cultivation by growers is beyond the scope of the breeder's work, deterioration due to genetical causes comes within the breeder's purview. In the case of cotton when once a strain has been released for distribution, the only thing we know is that the genetic variance has been reduced to such an extent as not to be detected by ordinary methods of plant breeding, but there can still be sufficient genetic variability left in the material which can exhibit itself in course of time. Though experimental proof is not available, it is possible that in quantitative characters controlled by a very large number of genes, there may be small mutations (East, 1935) and such mutations can result in deterioration. If the residual genetical variability left in the strain is such that the strain consists of genotypes some slightly better than others, deterioration can result by the gradual increase of the poorer ones. By the adoption of a small replicated progeny row test at the breeding station every year, we can weed out poorer genotypes from the material. Such deterioration due to genetic causes is known to exist even in self-fertilized cereals where the strains are from hybrids. Such strains are known to throw 'off-types' after some generations (Engledow, 1933) and the gradual deterioration in this case might be attributed to a residuum of impurity and the decreasing percentage of heterozygosity from generation to generation. In progenies of wide crosses such 'off-types' might occur due to cytological causes, losses in chromosome segments or even whole chromosomes (Love, 1939). It follows, therefore, that a well-organized scheme of seed multiplication and distribution must be continuously kept up. A nucleus must always be maintained at the breeding station to form the primary source for multiplication. The Cotton Committee have recognized this principle and are actually financing schemes for maintaining nucleus of cotton strains evolved at the breeding stations.

VII. Organization of Genetical Research.

In the preceding pages a brief outline of the plant breeding and genetical work in India has been given and indications made in what aspects the advances in genetical science can influence plant breeding practices. Plant breeding, as has been pointed out already, has a definite utilitarian end in view, namely, that the cultivator must get something more than what he gets now by growing the new variety put out by the plant breeder. This is, in fact, the touchstone for the ultimate success or failure of any plant breeding programme The attempt of the breeder to find something better than the existing one is, from its very nature, a never-ending scheme and hence the research has to go on continuously. Unlike other aspects of agricultural research, plant breeding work is capable of giving returns, several times that of what is actually spent on it and there is also the additional advantage of the results of plant breeding research being taken up readily by the cultivator as it involves no additional expenditure on his part

Though the advances in genetical science have come mainly from the work in organisms of no economical value like *Drosophila*, *Oenothera*, *Datura* etc., so far as India is concerned, the little genetical work that has been done is all related to agricultural crops. A great deal of genetical work even in these crops yet remains to be done. While part of it may be of practical value, it may include also other aspects which would simply add to our knowledge of these crop plants. The latter might be called basic research in genetics, and there must be some organization to carry on this work. The crop botanists of the provincial departments of agriculture have always got the pressing problem of producing improved types by ordinary breeding to replace existing types of crops and all of them cannot undertake problems of basic research either for want of time or want of facilities. Autonomous bodies created for individual crops like the Indian Central Cotton Committee for cotton have recognized the importance of such basic research. This body is financing a genetics research scheme in cotton. This basic research carried on at Indore is concerned mainly with one aspect, namely, research that has a direct bearing on plant breeding technique. The Jute Committee which has recently come into existence is expected to do for jute what the Cotton Committee is doing for cotton. The Imperial Department of Agriculture formerly at Pusa and now in Delhi is doing a considerable amount of plant breeding work of practical value and also a certain amount of basic research on genetics of crops. The Imperial Council of Agricultural Research is the other body created as a result of the recommendations of the Royal Commission on Agriculture that can arrange to see that such basic research in crops is carried on. The finances available with this body have been rather limited previously, but due to the passing of the Agricultural Produce Cess Bill recently, there is likely to be considerable improvement in the near future. This body has spent during the last 10 years (1929-30 to 1938-39) a sum of about 25 lakhs of rupees on crops generally, including all aspects of research besides another sum of about 16·5 lakhs on sugarcane alone. Of the former amount, nearly 50 per cent. has been devoted to financing schemes of rice research in provinces. This amount spent by the Imp. rial Council of Agricultural Research on crop research is in addition to what the Provinces and States are spending from their own budgets. It will still be worth mentioning that what is spent on this research in India, considering the size of the country, variety of crops and problems, will not compare favourably with what is spent on similar work in countries like Japan and Egypt. Towards plant breeding and genetical research, the former spends about 28 lakhs of rupees and the latter 5 lakhs of rupees annually. Looking into the nature of the schemes financed by the Imperial Council of Agricultural Research with regard to crops, with the exception of a few which can be termed basic research, the majority of them are of a routine nature, ordinary plant breeding schemes. Some of them are schemes either on new crops, for example, fruits, where no systematic work had been done previously or on crops which certain provincial departments of agriculture had not done any work on previously in spite of their importance to them. With regard to rice, a certain amount of basic research has been done under the schemes, but the bulk of them have dealt only with problems of local interest, namely, evolving improved strains out of local varieties in the Provinces. Even the programmes of basic research. I am referring only to genetics here, have not generally been on any preconceived and co-ordinated plan. There is no doubt that with greater co-ordination, more valuable results might be achieved. One example of what a good co-ordinated scheme of basic research can be, might be mentioned from America. Maize (corn) is the most important cereal of the country, perhaps not more important than rice to India, and every University or State Agricultural College is doing some work on the crop. In 1928, corn geneticists initiated a systematic study in which each of the 10 chromosomes of corn was assigned to workers in different institutions. This co-ordination of effort has eliminated much duplication and has speeded up the research programme to a remarkable extent. The inheritance of over 350 genes has been studied and their position in individual chromosomes has been determined.

Due to the initiative of the Imperial Council of Agricultural Research, methods of describing crop plants from the genetical point of view have been standardized with regard to the two crops, cotton and rice (Hutchinson and Ramiah, 1938*b*), and similar work is in progress with regard to other crops also. When the available material has been actually described according to the methods prescribed, it should go a long way in helping the breeder to understand the material available with his colleagues in other parts of India.

When the problem of plant breeding work in India was discussed before the Crops and Soils Wing of the Board of Agriculture in December, 1937, it was considered that plant breeding research may have to be carried on at several centres particularly in crops with limited adaptability, examples, rice and cotton, but that basic research should be confined to one or two selected centres only. Involved with the question of basic research is the question of crop introduction. The question of the formation of the Bureau of Plant Introduction under the auspices of the Imperial Council of Agricultural Research had already been discussed at two meetings of the Board of Agriculture, 1935 and 1937, and the principle has been accepted. Now that the finances of the Imperial Council of Agricultural Research are likely to be augmented, the question of the starting of an organization on the model of the Bureau of Plant Industry in United States of America might be considered. This bureau in America which works with headquarters at Washington has got on its staff a large number of eminent men on the different branches of crop research, and such men not only co-ordinate the various items of research in the different States, but also place at the disposal of workers or bring to the notice of workers of achievements in their branches recorded elsewhere. The Bureau is also in charge of the introduction of crops and plants into the country and arranges for their tests in suitable centres in co-operation with individual States. The Bureau also undertakes, whenever necessary, to send individuals and expeditions to various parts of the world to collect material of value for breeding purposes. Will it be too much to expect that a beginning on this model will be made in India?

While the advances in the science of genetics have been dealt with chiefly with reference to crops, the principles are of equal application to animals as well. The principles of genetics have hardly been utilized in the breeding of stock in India and I do not know whether genetics is ever taught to the students of the Veterinary Colleges. There is still another aspect of genetical science as applied to human race. The science of biometry in its application to genetics has been responsible for all our present-day knowledge on human inheritance (Eugenics). I am not sure that sufficient attention is paid to the teaching of eugenics to the students in any of our several Medical Colleges in India. A rough idea of the development of genetical science along diverse lines can be had from the papers that were contributed to the Seventh International Congress of Genetics held in Edinburgh in 1939. There were 353 contributions grouped as below:—

Gene and Chromosome theory and Cytology	... 61
Physiological genetics	... 46
Animal breeding in the light of genetics ...	... 53
Plant breeding in the light of genetics ...	... 46
Human genetics	... 51
Genetics in relation to Evolution and Systematics	... 52
Statistical genetics	... 17
Genetical aspects of growth—normal and abnormal	... 27
Total	... 353

VIII. Genetical Work and Universities.

Before I conclude I should like to say a few words about our Universities. There are seventeen Universities in India, almost all of them having affiliated colleges teaching up to Honours degree in biology but not one can still boast of a chair in genetics. The Honours students in Botany do, I believe, receive a few lectures on principles of Mendelism, but whether they get anything beyond that is very doubtful. Recent advances in genetics have had a profound effect on our knowledge of taxonomy and ecology, but still it is doubtful if students are made to get a grasp of such principles in their taxonomic studies, which so far as I know, still form a big portion of the botany syllabuses in the colleges. It is a point worth considering whether the taxonomical syllabus should not be cut down a little and the same substituted by genetical studies on agricultural crops. Even in connection with the taxonomical studies in the Universities, botanical excursions to key regions of agricultural crops and plants in co-operation with the crop botanists could be usefully undertaken. There is a wide field for this work in India particularly with our important crops, rice, sugarcane, fruit trees, etc.

There is one branch of botanical research in which several Universities have got competent Professors to undertake and guide research. I am referring to cytological research. From what has been said in the earlier portions of this address, it will be evident that most of the latest advances in genetics have come from cytological research. Still most of the cytological work done in India refers either to the embryo-sac development in some unimportant plant or determination of chromosome numbers. The plant breeders in the course of their work come across various problems necessitating intensive cytological studies which can easily be undertaken in the Universities. In some cases where crop botanists are making fundamental studies on their crop, they have their own cytological sections, but still I feel that this is a branch of botanical research in which the Agricultural Departments and the Universities can well co-operate in the interest of maximum output in the country. In recent times there have been a large number of brilliant young men who have gone abroad for intensive cytological studies and returned to India. Surely, it should be possible to make use of these men in this work. Even in other branches of botanical research, physiological genetics, for example, such a co-operation between crop botanists and Universities should prove extremely beneficial. I am mentioning the above points not with an idea of criticising the botanical work in the Universities, but to draw attention to the necessity for a change in the outlook. I am sure the difficulties, if there should be any, against such co-operative work, could be got over by personal contacts of individuals interested in common problems. The Imperial Council of Agricultural Research, when it was first formed, did have as one of its objects, bringing about a greater co-ordination between Agricultural Departments and Universities and it has succeeded to some extent in the attempt. Two instances of such successful co-ordination may be mentioned in this connection, namely, the rust work in wheat, and the general statistical work as applied to agricultural experiments. Let us only hope that such healthy contacts between workers in the Agricultural Departments and the Universities will be brought into effect in an ever-increasing measure, resulting in a greater output of basic research in the country.

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EXTRACTS

Save your own Tomato seed. Growers should exercise every care that tomato seed is taken only from strong, vigorous, and healthy plants of high productivity, and that the tomatoes selected should possess the necessary characteristics of the type which it is desired to produce and which will be most suitable for the locality where production is being carried on.

Selection intelligently and carefully carried out will give, in from three to five years, strains of seed greatly superior and better adapted to one's own conditions than any which it is possible to purchase.

Literature available on the subject is definitely in favour of home-grown seed selection as a means of improving the strain of the variety grown and also of increasing the yields of fruit. There is considerable evidence that yields can be materially increased by selection, and that home-grown seed from disease-free plants of high productivity and early maturity produces heavier crops than much of the purchased seed, particularly that of unknown origin. Seed taken from the product of low yielding plants will almost invariably produce weak plants of poor germination, while seed taken from the most productive and most uniform plants will produce the heaviest crops with a high percentage of uniformity. High productivity and early maturity can be obtained only from selected vigorous, healthy and disease free plants.

Plant Selection. To achieve these results, special attention should be paid to plant selection, and, in addition, good cultural practices must be adopted. Unfortunately, the fact that high prices may be paid for seed is not always a guarantee of high quality.

It has been established that certain plant diseases can be and are transmitted through the seed, and tomatoes are particularly susceptible to hereditary disease. In selecting tomatoes for seed, while many growers contend that they should be taken only from the bottom truss of fruit, exhaustive experiments carried out in seed production do not justify this contention. If, when secured, the tomatoes from which it is intended to extract the seed are not fully ripe, they should be kept in a reasonably warm place until well ripened. It may be noted, however, that vine-ripened fruit is considered best for seed production.

Method of Extraction. The tomato should be held in the left hand, and, with a sharp knife, cut through the centre at right angles to the stem, separating the fruit in two. Holding one half in either hand, cut surface turned downwards subject each to gentle pressure until the entire pulpy content is squeezed out into a scrupulously clean receptacle placed under the hands of the operator. By this method—through the rejection of the main bulk of the tomato—all the seeds are obtained, and, in the final washing, a great amount of labour will be saved.

After this operation is completed, the pulpy mass in the receptacle should be held at a temperature of not less than 65°—70°F for five or six days while fermentation takes place. Some growers stir the pulp occasionally with a clean piece of wood, but this is not necessary. Other growers allow the mass to settle, which results in a thick coating forming on top.

Washing the Seed. In washing the seed, plenty of fresh, clean water is absolutely essential. Assuming that the pulp has been kept in a clean petrol or kerosene tin and that this is half-full, the contents should be well stirred and the tin almost filled with water. A good plan at this stage is to use both hands for the purpose of gently crushing any lumps which may be among the pulp, as it will be noticed that quite a lot of seeds will be adhering to them. Having given the seed a little time to settle, and while the pulp is still floating among the water, start the process of separation by gently pouring out the contents from one "corner" of the tin until the seed is seen to appear. This operation should be repeated—using plenty of water—until the seed is separated from the pulp, when it is finally poured into a fine strainer and allowed to drain. After draining it may be spread out thinly and dried quickly,

Before storing for future use the seed must be perfectly dry. Damp seed will result in premature germination. As the "life" of tomato seed is from five to six years, a considerable quantity can be produced from one crop. There are from 5,000 to 6,000 seeds in one ounce, and the germination of one-year-old seed ranges from 70 per cent. to 85 per cent.

This method of tomato seed extraction is equally applicable to the small grower, provided, the suggestions made are adopted and the directions given are followed, *New Zealand Jour. Agri.* 1941 62, 260—261.

A New Species of Coleus. *Coleus vettiveroides*, K. C. Jacob. Herb succulent, 45 cm.—53 cm. in height, bushy with slightly decumbent branches; stem 1·25 cm. in diameter, slightly purplish, pubescent with white short hairs, main stem more or less four-sided and branches nearly terete; leaves opposite; petioles 4 cm.—6 cm. long, pubescent, purplish, ventrally furrowed dorsally rounded (terete); lamina thick, nearly rounded 8 cm.—10 cm. long, 9 cm.—12 cm. broad, sparsely pubescent on the upper surface and densely pubescent below; nerves palmate, main nerves 12, margins dentate. Roots fibrous 35 cm.—50 cm. long when grown in sandy areas, straw-coloured, turning dark after a day or two, aromatic when fresh. The plant has so far been seen only under cultivation at Shiyali, Tanjore District; Palni in Madura District; Conjeeveram in Chingleput District, etc., in the Madras Presidency, and it has not been seen in flower anywhere at any time. The plants were specially grown at Shiyali in Tanjore District, South India, a natural habitat and at Coimbatore. All attempts at inducing flowering have failed at both places. There is a specimen of this plant in the Madras Herbarium at Coimbatore labelled *Coleus osmirrhizon* Elliot. Tamil: Kuru Veru, collected at Mahabalipuram, Chingleput District, by T. Abboy Naidu on the 25th May, 1879. This name (*Coleus osmirrhizozn* Elliot) could not be traced in any of the literature available here. The Curator of the Herbarium, Royal Botanic Gardens, Sibpur, Calcutta, considers it as only a manuscript name. This specimen also is without flowers. There is a good deal of confusion in the local name of the scented roots of *Vetiveria zizanioides* Nash. (a grass) and those of this species of Coleus, the specific name of which has not been determined. With a view to clarify this confusion, a questionnaire was sent to some of the most important places where these two roots are very well known locally, and information obtained through the Agricultural Department Officers. Four local names, *viz.*, Vetti ver, Kuru ver, Velamichai ver and Ramacham were reported to be in common use for these two scented roots. The consensus of opinion is that Vetti ver and Kuru ver are synonyms and are used for the roots of the Coleus species and Velamichai ver and Ramacham are two linguistic names for the grass, *Vetiveria zizanioides* Nash, the former in Tamil Districts, and the latter in Malayalam speaking Districts and States.

The roots of this Coleus species are known as Vettiver in Tanjore, North Arcot, Coimbatore, Madura, Tinnevelly and Ramnad Districts. The same root is known as Kuru ver in Chingleput, Tanjore, North Arcot and parts of Madura Districts. Vetti ver and Kuru ver are synonymously used in Tanjore, North Arcot and parts of Madura Districts.

In Shiyali Taluq of the Tanjore District where this Coleus species is extensively cultivated on the sandy banks of the Coleroon river, the names Vetti ver and Kuru ver are synonymously used. At Palni in Madura District where it is under cultivation in sandy garden lands it goes by the name Vetti-ver and at Conjeeveram in Chingleput District where it is cultivated on the banks of the Vegavathi river it is known as Kuruver.

The fresh fragrant roots of Vettiver (Kuruver) are used from time immemorial in the decoration of the idols in the South Indian temples of the Tamil Districts and also in the ladies' toilet for dressing hair.

The well-known Khus-khus or Cuscus of Commerce is known as Velamichai or Velamichaver in all the Tamil Districts. Viz., Tanjore, North Arcot, Madura, Tinnevelly, Coimbatore, etc. In parts of Tinnevelly District it is also known as Lamachan or Ramacham Ver. Ramacham is the well-known name for this root unmistakably used throughout the Malayalam speaking area. It is called Vetti ver at Vellaikulam in Chingleput District adjoining the Telugu area.

The fragrant dried roots of the Khus-khus are used for making mats, chick-thatties, fancy fans and 'Kavadies'. It is also employed in the adulteration of Vettiver at Srivilliputhur, Ramnad District. These roots are scented only at certain seasons of the year (Madras Agricultural Department Year Book 1918, pp. 67–69). It is extensively cultivated on the coastal regions of the Ponnani Taluq of the Malabar District It is also grown to a limited extent at Srivilliputhur in Ramnad District mainly for adulterating with the roots of Vettiver (*Coleus sp.*). This grass is found commonly in swampy or moist situations in Mysore, South Kanara, Malabar, Coimbatore, Chingleput, South Arcot, Nellore, Kistna, Godavari, Vizagapatam and other Districts. But the extraction of Khus-khus at the proper season and the manufacture of chick-thatties, fans, etc., are carried on as a cottage industry by the moplah community (Malayalam speaking Muhammadans) of the Ponnani taluq in the Malabar District.

The dried roots of this grass retain the pleasant and strong aroma for a very long time even for some years, while only fresh roots of Vettiver (Coleus sp.) are scented and made use of since they become odourless as they dry up in the course of 3 or 4 days. The fresh Vettiver roots are strawcoloured but soon become dark as they dry up, while those of Khus-khus retain their straw colour even after drying.

In the Telugu Districts of this Presidency starting from the Chingleput District right up to Ganjam, Khus-khus roots are known as Vetti ver. The idols in the Telugu temples are not generally decorated with any scented roots. Since khus-khus is known as Vetti ver, the products of Khus-khus, viz., chick-thatties, fans, etc., are also known as Vettiver thatties, fans, etc., in these parts.

It has already been shown that Khus-khus and Vettiver (also known as Kuruver) are the roots of two different kinds of plants but are recognised by different conflicting names in different localities of this Province. This misnomer in the local names has been carried so far that the local name of the Coleus species was given to a species of grass, *Vetiveria odorata* Virey., as early as 1827. Hooker, in the Flora of *British India*, puts Vetiveria as a subgenus of Andropogon and called this plant *Andropogon squarrosus* Linn. f., but Gamble, in the *Flora of the Presidency of Madras*, names this grass as *Vetiveria zizanioides* Nash. The local name of this *Coleus* has become the generic name of a group of grass, one of which has scented roots.

Vettiver or Kuruver (*Coleus* sp.) is largely cultivated on the river banks in sandy loams. It is propagated by planting young shoots and plants are ready for lifting in about 4 months when the roots would have attained the maximum length and possessed with best aroma. It needs heavy manuring and constant watering.

This species of Coleus which has not so far been correctly named is designated as *Coleus vettiveroides* K. C. Jacob. The specific name *vettiveroides* is after the most popular Tamil name of the plant in places where it is largelv cultivated. K. C. Jacob, *Jour. Bom. Nat. Hist. Soc.* Vol. XLII, No. 2, 1941.

Gleanings.

Stimulation of Root Formation of Sugarcane with Ethyl Alcohol. The desirability of ensuring root formation for studies on germination of sugarcane led to the treatment of seed pieces with various growth-inducing substances, including indole butyric acid, water, ammonium phosphate, calcium nitrate, and ethyl alcohol. A 5 per cent. solution of 95 per cent. ethyl alcohol proved to be the most effective treatment for stimulating root formation, especially at low temperature (69°—75°F.). Optimum time of treatment was between 24 and 48 hours. Less stimulation occurred in young seed pieces than in more mature planting material, suggesting that the ethyl alcohol serves as a readily available, high-energy food. *Hawaii Agr. Exp. Sta. Rep.* 1940—37.

Agricultural Improvement means Agricultural Education. The present lack of training facilities for young people in agriculture is probably largely responsible for the lag there is in the industry between the proved value of new knowledge and its application. In contrast with this we have the gratifying and, indeed, remarkable fact that great additions to our knowledge of agricultural problems have been made by British scientific workers in many branches during recent years and, alongside them, the demonstration of their commercial value has been proved in many directions. The feeding of livestock, the improved treatment of grassland, the value and preparation of ensilage, improved knowledge of manuring and many improved methods in vegetable and fruit production are familiar examples. It is not too much to say that the names of some of our chief agricultural research workers and of their institutes are known all over the world, but I believe, it is true to say that there are thousands of British farmers who have only the vaguest idea as to what these men stand for—if any idea at all.

Our Agricultural Colleges and Institutes and the staffs employed by county councils have done splendid work in evoking the interest of farmers and in spreading knowledge in the face of great difficulties, but I have not met one of