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Maximisation of Production by the Cultivation of Hybrid Strains with Special Reference to Cumbu (Pearl Millet)

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Introduction: The phenomenon of hybrid vigour has engaged the attention of plant breeders and geneticists from very early times. In recent years, the utilisation of hybrid vigour or heterosis, for improvement of crop yields has brought forth very valuable results. In naturally cross-pollinated crops, continued inbreeding results in loss of vigour of the progeny and consequent reduction in yields. Hybridisation between the inbred types, in cross-pollinated crops, is usually accompanied by greater vigour in the resulting progeny leading to phenomenal increases in yield. This factor, coupled with the ease of hybridisation on a large scale, paved the way for the exploitation of hybrid vigour as a method of maximisation of production in these crops. The results achieved in one of them, maize, have clearly demonstrated the potentialities of this method and have revolutionised corn production in all the corn-growing countries of the world. The remarkable achievements attained in corn production, through the introduction of hybrid strains, have stimulated investigations on similar lines in other cross-pollinated crops. Among Millets, *Cumbu* has responded remarkably well and the results obtained from preliminary studies, at the Millet Breeding Station, Coimbatore, are briefly presented in this paper.

Causes of Hybrid Vigour: Different interpretations of the causes giving rise to the phenomenon of hybrid vigour have been given by various workers in this field. Keeble and Pellew (3) explained the increased vigour of a cross between two varieties of peas, as due to the dominance of the thick stem of one parent and the long internode of the other. This was not found generally applicable, as other cases of manifestation could not be explained on an equally simple basis. Jones in 1917 (1) developed the hypothesis of "Dominance of Linked Genes" giving hybrid vigour a factorial interpretation. This has been accepted by most plant breeders and geneticists. He maintained that numerous genes were responsible for the expression of quantitative characters and that some of the genes responsible for yield were at least partially dominant. The increased vigour of the hybrid, according to him, was due to the action of different dominant growth factors, contributed by each parent. Jones (2) has recently shown that apparently degenerative changes in six mutations in homozygous inbred lines of maize produced a notable degree of heterosis, when these mutants were crossed with the original inbred parents. On these findings, he interprets heterosis as an accumulative effect of favourable heredity from both parents.

The Floral Mechanism in the Pearl Millet: Among the millets, *Cumbu* is the most highly cross-fertilised crop. Unlike most of the grasses, the stigmas of this millet mature earlier than the anthers, resulting in protogyny and cross-pollination. The inflorescence is a terminal compound spike with a variable number of rachillae, spirally arranged round a central axis. The rachillae which vary in length, bear at their apex a whorl of bristles enclosing two spikelets, each of which consists of a male and a hermaphrodite flower. Flowering commences at the

tip of the panicles by the protrusion of the stigmatic branches of the hermaphrodite flowers. This process is continued in the lower spikelets, and proceeds downward to the base taking about two to three days for completion. This protrusion of the anthers and the dehiscence of pollen commence only after the stigmatic emergence with the result that, when the top anthers begin to shed pollen, the emergence of stigmas would be almost complete in the whole panicle. The anthers in the hermaphrodite flowers of the panicle, situated slightly below the tip emerge and shed their pollen first. The protrusion of anthers further proceeds upwards and downwards along the panicle, till the tip and base are reached. At this stage, another flush of anthers takes place from the unisexual flowers of the spikelets which supplements the pollen supply for fertilisation. The process of anthesis is completed in about 4 to 5 days. The interval between the emergence of the stigmas and the commencement of anther dehiscence is two to three days, and as the stigmas are quite receptive and exposed to wind, that may carry foreign pollen, natural cross-pollination takes place to a great extent. This has been already recorded in a previous paper (13). It was found that natural crossing in *Cumbu* varied from 27 to 78%. Being so highly cross-pollinated, it is to be expected that natural populations of this crop are mixtures of heterozygous individuals. Continued selection may help to isolate some true breeding and fairly vigorous types. But it is beset with difficulties. It was hence considered desirable to investigate the possibilities of taking advantage of its natural cross-pollination for utilising hybrid vigour for increasing its yield.

Preliminary Investigations on the Production of Hybrid Strains in Pearl Millet: Preliminary studies for the evolution of hybrid strains in *Cumbu* were started at the Millet Breeding Station, Coimbatore, in 1943. In the first year, 15 crosses were made between eight different types of *Cumbu* and they were compared with their parents, in row yield trial plots in the following season. It was observed that in three crosses, the hybrids yielded more grain than both of their parents, the increases ranging from 16 to 163%, and in five others the hybrids yielded higher than one of the parents only. Thirty-eight crosses were made in 1944, and 23 of these yielded more grain than both of their parents. Forty-eight crosses were made in 1946 and tested in the following season, when 11 of them yielded more grain than both of the parents. These results clearly indicated that there was great possibility of obtaining increased yields in *Cumbu* through the introduction of hybrid strains.

Hence detailed work on the evolution of hybrid strains of *Cumbu* was taken up under a scheme sanctioned by the Madras Government from 20th March 1946 to 19th March, 1950. Hundreds of fresh samples of seeds of *Cumbu* were collected and studied, and promising selections isolated from them. These were inbred, crossed, and the hybrids studied to test their yielding capacity and other economic characters. More than 880 crosses were made in the period up to 1950, and 743 of these were tested for row yield trial in small plots and preliminary yield trial in larger plots. Only 25 of these hybrids were significantly superior to both of their parents and the standard, while 39 were superior to both of their parents, and 102 gave higher yields than one or the other of their parents, or standard. The promising hybrids in such tests were multiplied on a large scale by growing the parents side by side in two row plots and hand pollinating sufficient number of female plants to get enough seed for conducting yield trials in larger plots for comparison with the parents and standard. The best of these hybrids were given out for district trials. The primary object of the investigation being the economic utilisation of hybrid vigour, stress was laid on the grain yield of the hybrids as compared to that of the parents and standard. To provide further evidence of the manifestation of this phenomenon, the fresh weight of straw of the hybrids was also noted. The majority of the hybrids which gave significant increases in yield over the standard resulted from crosses between types which were widely separated in their origin. The types from Sind or the Punjab figured as valuable parents. Similarly maximum increases in yield were almost met with in these hybrids, thereby establishing the superior combining ability of widely separated types. These results indicated that in the Pearl Millet, as in the case of most of the naturally pollinated crops, heterosis is manifested in the

progeny, when different types are hybridised. Heterosis is expressed in varying degrees, but the greater the diversity of origin of the parents, the greater is its manifestation. Certain of the types included in the present studies show a high degree of combining ability in crosses with others, and the increases in yield of grain are so high, as to deserve special attention for economic exploitation. Among the hybrids so far produced, X. 1 and X. 2, which were isolated earlier, were subjected to systematic trials from 1946 onwards. In the first year, the hybrid seeds were produced by sowing their parents in alternate lines, the male parents being sown three days earlier than the female parents. The female lines, bearing the hybrid seeds, were harvested separately. These seeds were put in yield trial plots in 1948. Data showed that the hybrids were significantly superior to the standard and their female parents. In subsequent trials, the hybrid seeds were produced by artificial pollination, and tested in comparative yield trial plots.

Taking all the yield tests, both the hybrids were significantly superior to their parents, and also the standard strain Co. 1, which by itself is a high yielder, and hence both the hybrids were advanced to the next stage of work viz., trials in the fields of the cultivators.

Trial of Hybrids in the Districts: To test the suitability of the best of these hybrids in the different districts of the State, extensive trials in cultivators' fields are necessary.

The hybrids – X. 1 and X. 2 were sent to eight different taluks in the districts of Tiruchirapalli, Coimbatore, and Tirunelveli in 1948 for conducting trials in large sized observation plots along with the local variety of *Cumbu* for comparison. In Musiri taluk in Tiruchirapalli the trials were conducted at two centres and X 1 gave an increased yield of 61% and X. 2 gave 60% over the local type. In the trials conducted in Perambalur taluk, 14% increased yield over the local in the case of X. 1 and 74% in the case of X. 2 were obtained, and the cultivators were very much impressed by the performance of X. 2. The hybrids were not found suitable for Tirunelveli district in this trial. In 1949, both the hybrids were sent out for extensive trials in 66 taluks, distributed in 17 districts viz., South Vizagapatam, West Godavari, Guntur, Bellary, Nellore, Kurnool, Cuddapah, Anantapur, Chittoor, North Arcot, Salem, South Arcot, Tiruchirapalli, Madhurai, Ramnad, Tirunelveli and Coimbatore. Reports received so far on the trials conducted in the districts indicate that both the hybrids are superior to the local types in most of the southern districts of the State. Results showing the superiority of the hybrids X. 1 and X. 2 over the local types were received from the taluks of Musiri, Perambalur and Karur in Tiruchirapalli District, Arupakottai and Mudukulathur in Ramnad District, Dindigul in Madhurai District, Attur, Namakkal, Tiruchengode and Omalur in Salem District, Kallakurichi in South Arcot District, Coimbatore in Coimbatore District, Koilpatti in Tirunelveli District, Vayalpad in Chittoor District and also Harpanahalle and the Agricultural Research Station, Siruguppa in Bellary district. Increases in yield over the local varieties ranging from 12 to 220% in the case of X. 1, and from 11 to 260% in the case of X. 2 have been reported from the places mentioned above. Reports of trials conducted in South Vizagapatam, Cuddapah and Nellore show that these hybrids are not suitable for these tracts. The districts and taluks where the hybrids have been found suitable and increases in yield over the local types are given in the following tabular statement.

Districts and Taluks, where the hybrids—X. 1 and X. 2 are found suitable (1949–1950).

District	Name of taluk	Centre of trial	Yield expressed as percentage of local		
			X. 1.	X.2.	Local.
Salem	Namakkal		130	139	100
,,	Trichengode		...	113	100
,,	Attur	Ammanpalayam	168	136	100
,,	Omalur	Arthukavanur	120	...	100

District	Name of taluk	Centre of trial	Yield expressed as percentage of local		
			X. 1.	X.2.	Local
Coimbatore	Coimbatore	Ondiputhur	156	145	100
Madhurai	Dindigul	Thadicombu	168	...	100
Ramnad	Arupukottai	Kanjanaikenpatti	172	119	100
,,	,,	Ramanujapuram	122	111	100
,,	Sattur	Vellayapuram	135	144	100
,,	,,	Mutbulingapuram	124	130	100
,,	Mudukulathur		145	153	100
Tiruchirapalli	Musiri	Chithalarai	188	161	100
,,	,,	Valavandi	161	163	100
,,	Perambalur	Perambalur	114	174	100
,,	Karur	Rangapalayam	181	171	100
Tirunelveli	Koilpatti		129	132	100
South Arcot	Kallakurichi	Kurur	220	260	100
Bellary	Harpanahalli		132	121	100
,,	,,		128	119	100
,,	Agricultural Research Station, Siruguppa		112	115	100
Chittoor	Vayalpad		...	118	100
		Average	148%	144%	

From the above statement, it will be seen that these two hydrids are capable of giving much higher yields than the local types in most of the southern districts of this State. As already indicated above, there are tracts where these hybrids have not been found suitable. Regional work has been take up for such tracts, and hybrids made from zonal collections are awaiting trials in such tracts. Apart from the two established hybrids, 32 more are in various stages of trial and they too offer a wealth of material for final choice after comparative yield studies. Along with the work on these hybrids, systematic studies and inbreeding are also in progress for the isolation of standardised types for hybridisation, so that hybrids with specific combinations of characters suitable for different tracts and sub-tracts can be evolved.

Discussion: In an unselect sample or variety of a normally cross-pollinated crop, many of the genes responsible for vigour may occur in a heterozygous and randomly disributed condition. Continued inbreeding will result in the production of a number of separate strains, with a progressive increase in the number of such factors in a homogyous condition. This inbreeding and selection leads to a separation of factors on whose combined presence depends the original vigour, and it also eliminates rapidly those deleterious recessives which produce such unwanted characters as dwarfness, sterility, chlorophyll deficiencies etc. Thus as a result of inbreeding, a large number of strains are obtained which, though poor in yield, are free from the grosser defects and are uniform in their genetic constitution. If two such strains are intercrossed, a recombination of

factors occurs, giving rise to a hybrid which is more vigorous than the parents. In order that this vigour is obtained uniformly and to the maximum extent, it is necessary that the combining ability of the parents should be tested in various combinations and inbreeding should also be carried out simultaneously to attain a high degree of homozygosity. It is observed that vigorous inbred parents do not always give proportionately vigorous hybrids, showing thereby that no standards can be fixed for selection of characters responsible for hybrid vigour The only method to judge the merits of a type is to test it by crossing with several others. The stage of inbreeding, when the parents are fit to be tested by crossing, cannot also be definitely determined so as to attain maximum homozygosity of inbred lines, which will assure increased vigour in the hybrids. In crops where hybrid vigour is utilised on a commercial scale for increased production, crossing is done at a very early stage. Top crosses, wherein commercial varieties are crossed with inbred lines, are considered of much value in testing the efficiency of parents. Combining ability being established as an inherited character, it may be expected that the performance of hybrids between plants of unselected bulks can be taken as the criterion for selection of promising types. As indicated by the results presented above, heterosis on an economically appreciable scale, is expressed in the Pearl Millet and it is worthy of commercial exploitation. The combining ability of different types and the varying degrees to which it is expressed in particular crosses is clearly brought about by the present studies. By inbreeding the types, which have shown great combining ability, it is expected that inbred lines with desirable characters can be crossed to secure the required type of hybrids. The methods of large-scale production of hybrid seeds for distribution is a problem demanding particular attention in this crop, due to the peculiar floral mechanism of the plant Unlike in maize, where detasselling of female parent rows will completely eliminate the possibility of self-pollination, absolute prevention of the same, on a field scale, cannot be achieved in *Cumbu*, due to the hermaphroditic nature of the flowers, and the consequent self-pollination of the lower flowers of the spike by the pollen of the top flowers. Perhaps induction of male sterility in female rows may assure complete cross pollination. But attempts so far made to induce male sterility have not been successful.

The preliminary studies made so far at the Millets Station, have indicated the high degree of cross-pollination (70 to 80%) that takes place in this crop; and that itself serves as an easy method for the production of hybrid seeds. Cross-pollination to the extent indicated above could be obtained by sowing the two parents in adjacent rows and also by mixing the seeds of the parents. As this method is both easy and cheap and as it guarantees a high degree of cross-pollination resulting in increased yield. it is being adopted for large scale production.

Conclusion: The evolution of hybrid strains in *Cumbu* is more or less a new line of plant improvement work, This is on the model of the production of hybrid corn, which is an established agro-industry in the United States of America and other corn-growing countries of the world. In the United States of America, it took more than 25 years of research work to evolve the first commercial hybrid. But in India, it has been possible to evolve two high yielding hybrids in the course of four years of work at the Millets Breeding Station, Coimbatore. These two hybrids X. 1 and X. 2 have established their suitability over a very large area in nine district trials is 48% over the local types in the case of X. 1 and 44% in the case of X. 2. Taking the average increased yield over the local types to be 45%, it may be estimated that an annual extra yield of more than 80,000 tons of *Cumbu*, valued over Rs. 170 lakhs, can be obtained from these

strains, if half of the entire area under cumbu in the nine districts is brought under the hybrid strains. Six more hybrids have passed the experimental stage and await trials in the districts. When the trials are completed, these too will be available for spread according to the special needs of the different tracts in this State.

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Pretreatment - A New Aid for Improving Crop Yields

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It is the object of this paper to just outline a few of the results obtained in the direction of improving yields by a new method—that of supplying nutrient elements to plants before they are sown.

It is course a truism to say that good crops are assured by good manuring, in the same way as good food makes for sturdy men and women. What is not so widely known is the fact that for plants too, a little help in the early stages, goes a long way in improving the subsequent growth and their ultimate yields in the same manner as a liberal supply of milk and milk products to children helps in laying the foundation for a strong and healthy manhood. The basic principle underlying the idea of pretreating seeds with nutrient salts is to introduce into the seed enough of the major nutrients like phosphorus and potassium in a readily available form, sufficient to carry the young plant through its early stages, before its root system is sufficiently developed to make full use of the available supplies of these nutrients in the soil.

In the present day context of all-round scarcity, for everything from a match box to a motor car, it is imperative to use what we do have, to the best advantage and make a little go a long way. The question of supplying fertilizers to crops is no exception to this rule