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GENETIC DIVERGENCE AND PHENOTYPIC STABILITY IN SOME INTERSPECIFIC HYBRIDS OF EU-SORGHUM

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The genus *Sorghum* possesses considerable genetic diversity among its numerous cultivated forms which are capable of growing under wide agro-climatic conditions and which are utilised for diverse purposes. A study of the nature of genetic divergence utilising D^2 statistic revealed that the sub-genus Eu-Sorghum could be divided into nine species (Chandrasekhariah, Murty and Arunachalam, 1969). The divergence in the male parents used would be reflected to a certain extent in the phenotypic stability and performance of hybrid derivatives of these with a common male parent, MS. CK 60.

It would also give an idea of thc effect of each genotype in a common maternal background, permitting a comparison of the haplo-effect of the male parents. The results of such a study are reported in this paper.

Materials and Methods

The material comprised twelve populations representing the sub-section *Arundinacea* (Snowden, 1936), their twelve F_1 hybrids with the common female parent, MSCK–60–A and its fertile counterpart, MSCK–60–B.

The material was grown in Delhi during 1963 in a randomised block design with three replications. Other agronomic details of the experiment were identical to those reported in an earlier paper (Chandrasekhariah *et al.*, 1969). Observations were recorded on a random sample of ten plants per line on growth rate (cm./day), days to flower, plant height (cm.), leaf length (cm.) and panicle length (cm.).

Using the common error dispersion matrix of the character means, the values of D^2 for all pairwise combinations were computed and on this basis, the parents and hybrids were grouped following the procedures outlined in Rao (1952).

Results

The five characters scored are considered to be important in the production of total dry matter. The effect of the female parent on the performance of hybrids was observed (Chandrasekhariah, 1964) in general, in the erectness and coriaceous nature of leaves having entire margin, the earhead shape tending towards oblong-cylindric and semi-compact condition, the shape of sessile spikelet tending to be elliptic-ovate, the pedicellate spikelet being neutral and in the reduction in pollen fertility. Increase in growth rate of the

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TABLE 1

Analysis of variance of means (M) and transformed plot variances (V) for 12 *parents and their hybrids in* Sorghum

Source	d.f.	Growth rate (cm/day)		Days to flower		Plant height (cm)		Leaf length (cm)		Panicle length (cm)	
		Mean Squares									
		M	V	M	V	M	V	M	V	M	V
Treatments	24	1·97**	0·45**	647·45**	0·74**	19455·90**	0·57**	627·85**	0·21**	95·23**	0·27**
Hybrids	11	0·87**	0·51**	664·31**	0·55**	16837·30**	0·58**	529·38**	0·23**	55·97**	0·37**
Males	11	1·13**	0·43**	691·17**	0·85**	18528·10**	0·37*	701·51**	0·21**	138·06**	0·20**
Males vs. Female	1	8·58**	0·46**	286·07**	0·57	41384·10**	2·81**	132·62**	0·08**	12·97**	0·01
Hybrids vs Parents	1	16·75**	0·001	342·36**	1·69**	36539·50**	0·29*	1395·86**	0·003	138·26**	0·22*
Error	48	0·13	0·04	9·13	0·22	188·9	0·15	0·69	0·16	1·08	0·05

*Significant at 5% level **Significant at 1% level.

hybrids over their male parents was comparatively lower than that over the female parent, except in the cross involving *S. virgatum*. The hybrids were earlier to flower than both the parents in the crosses involving *S. virgatum* and *S. nervosum* while, in other cases, the hybrids tended to be earlier than their male parents only. In general, hybrids were superior in performance than the parents for plant height, leaf length and panicle length barring a few exceptions.

Anova of means (Table 1) clearly indicated that highly significant differences existed for all the characters. From the comparison, parents vs. hybrids, it could be inferred that the hybrids were quite vigorous compared to the parents. The variance due to males for panicle length was more than double that due to hybrids indicating the moderating role of the female parent on the observed differences.

The plot variances were transformed to log scale and were analysed to detect differences in the phenotypic variability within plots in each treatment. Since the sample size was equal for each plot, weighted analysis was unnecessary. A comparison of the variances (Table 1) showed in general lower variability for hybrids within plots than for their male parents for growth rate, days to flower and plant height. The hybrid involving *S. conspicuum* exhibited higher variability in plant height than either of its parents. Most of the hybrids showed higher and a few lower variability than their corresponding parents for leaf and panicle length.

Significant differences among the treatments, among the hybrids and among the male parents were noted for all the five characters. The variance of the comparison, hybrids *versus* parents, was low in all the characters indicating its similarity among non-segregating generations.

The divergence of the hybrids from the parents on the basis of the five characters estimated by D^2-statistic are given in Table 2. The hybrids were closer to their male parents than to their common female parent in all cases except the two cases involving *S. virgatum* and *S. caffrorum*, where the hybrids were closer to the female parent. An examination of the relative contribution of the characters revealed that panicle length was the major contributor to genetic divergence except in the cross involving *S. nervosum* where days to flower was the major contributor followed by panicle length.

The divergence was also determined by canonical or principal component analysis. Following the procedure given by Rao, 1952, the standardised best linear functions (canonical vectors) were obtained (Table 3).

The first canonical root alone accounted for 90·8% of the total variation. A two-dimensional representation using the means of the first two canonical vectors (Fig. 1), confirmed the observation based on D^2-statistic that the hybrids were closer to male parents than to the female parent, except in the case of the F_1, MSCK-60 × *S. dochna*. An examination of the coefficients of the canonical vectors (Table 4) shows that panicle and leaf length played a major role in the divergence of the populations followed by days to flower and plant height.

TABLE 2

D^2 between 12 *hybrids and their respective parents in* Sorghum

Hybrid	D^2 between the hybrid and the female parent	D^2 between the hybrid and the male parent
MSCK–60 × *S. virgatum*	10·87	126·70
MSCK–60 × *S. drummondii*	1·34	0·77
,, × *S. conspicuum*	186·69	13·49
,, × *S. roxburghii*	47·98	6·55
,, × *S. caffrorum*	2·74	27·26
,, × *S. dochna*	82·69	15·91
,, × *S. cernuum*	85·02	6·29
,, × *S. cernuum*	107·16	72·10
,, × *S. subglabrescens*	130·37	15·23
,, × *S. membranaceum*	151·94	20·98
,, × *S. nervosum*	0·52	0·36
,, × *Milo*	13·35	0·40

TABLE 3

The first two canonical vectors for 12 *hybrids and their parents in Sorghum*

	Y_1	Y_2	Y_3	Y_4	Y_5
Z_1	0·0219	0·0777	0·0663	0·3032	0·9470
Z_2	0·0784	0·7138	0·6806	0·0493	–0·1351

$Y_i = \sum_{j=1}^{i} k_j x_j$ is the uncorrelated linear function of x's—x_1 = Growth rate; x_2 = Days to flower; x_3 = Plant height; x_4 = Leaf length; x_5 = Panicle length.

DISCUSSION

An earlier study (Chandrasekhariah *et al.*, 1969) of nearly 50 species representing the whole genus *Sorghum* has clearly brought out that the conventional methods of classification based on phenotypic measurements made generally in laboratory specimens do not lead to correct results and hence have to be replaced by more effective methods. As found in several disciplines (Rao, 1952), D^2 statistic was found to be the best tool for classification of biological populations as well. It was found to provide an effective measure of genetic divergence between any two populations. In this connection it should be stressed that the criteria of choice of characters should be sound.

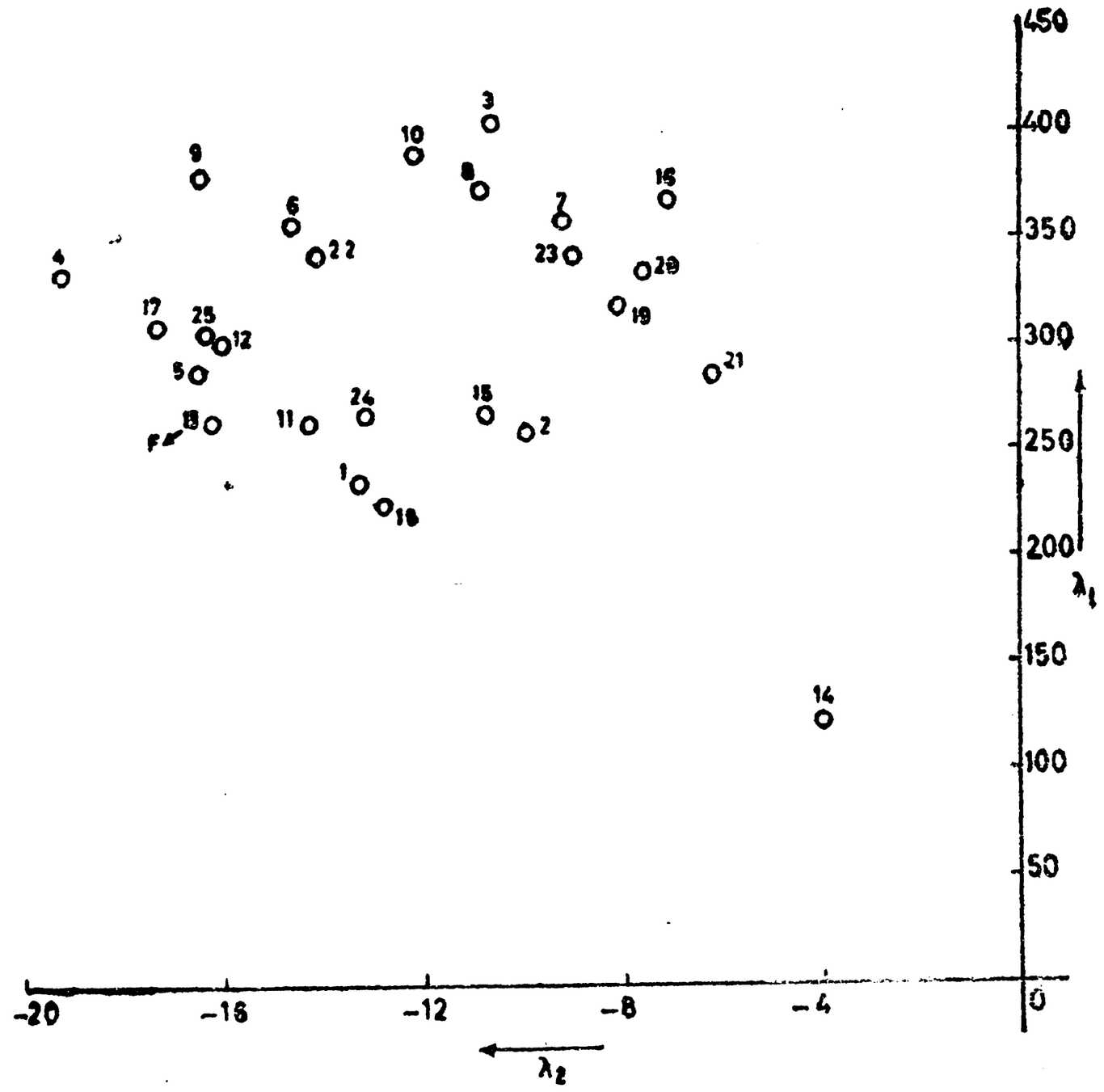

Fig. 1. The disposition of parents and inter-specific hybrids in *Sorghum*

It is generally found fruitful to include all the characters related to fitness and contributing to yield. The genus *Sorghum* was reclassified (Chandrasekhariah *et al.*, 1969) utilizing ten characters and five of them were found in that study to be very important for measuring genetic divergence. These five characters were hence chosen for the present investigation.

This study dealing with hybrid analysis against the common genetic background provided by the male sterile combine Kafir 60 was also in a way, an adequate check on our classification of the genus *Sorghum*. It was found that the classification by D^2 of the parents and hybrids was in good conformity with the earlier one. The hybrid involving *S. roxburghii* was the lone exception. It is likely that the hybrid included here has not represented the wide variability of this species resulting in the observed differences from the previous classification. The grouping obtained using D^2-values was adequately supported by the canonical analysis. The classification by D^2-statistic and hybrid analysis has found wider applications and been substantiated in the classification of a large number of genetic stocks and the utility of the characters studied in factor analysis also (Murty, Arunachalam and Jain, 1970). The superior role of some hybrids was brought out by the position of the hybrids relative to their male parents (Fig. 1).

The differences between hybrids and male parents were not pronounced in growth rate unlike plant height and panicle length. The hybrids, though

slightly earlier to flower, possessed longer panicles and were generally taller than the male parents. However, since the hybrids are relatively better in performance, it would be possible (a) to choose desirable segregates in advanced generations and (b) to obtain superior hybrids by diversifying the male parents by choosing from different height and maturity ranges.

As observed by Dobzhansky and Pavlovsky (1958) in *Drsophila*, recombinations in crosses between widely divergent populations resulted in reduction of heterosis which was conditioned by the co-adapted gene complexes. Such a divergence is reflected not only in the means but in the variances of the hybrid population as revealed by the present study.

While the phenotypic variability due to genetic differences within a population is deisrable for selection, phenotypic variability of F_1's is not desirable for breeding work, where the F_1 hybrids have to be cultivated, as in maize, *Pennisetum* and *Sorghum*. Since MSCK-60 has been found to be a desirable female parent in the hybrid *Sorghum* programme, the higher variance in some of the hybrids say, for example, the one involving *S. conspicuum* stresses the need to test the hybrids in a range of environments and recommend them only to those areas in which they can adapt themselves and be stable in performance.

Summary

An analysis of the divergence of the hybrids between MSCK-60 as a common female parent with 12 different species as male parent representing the sub-series, along with the parents by D^2-statistic confirmed the relationship between the species. Canonical analysis of the above hybrids supported the grouping obtained on the basis of D^2. The hybrids were, in general, closer to male parents, than to the female parent in both the analyses.

The divergence between parents was reflected in the means and variances of hybrids, as revealed by the present study. The implications of the results are discussed.

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