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GENETIC ANALYSIS OF SOME EXOTIC X INDIAN CROSSES IN SORGHUM VI. CHARACTER ASSOCIATION UNDER SELECTION

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In a study of the nature of association of characters in F_2 populations of exotic × Indian crosses of sorghum, Harinarayana, Rao and Venkatraman (1971) noticed pleiotropic effects of height and maturity genes on yield as well as linkage. Subsequently, Reddy and Rao (1971), in a study of F_4 and F_5 populations, found that the direct effects of height and maturity on yield were still pronounced while the indirect effects were dissipated during the process of selection. In the present paper, the results of further studies on the nature of association between plant height, days to half-bloom and yield in nearly homozygous F_6 and F_7 populations, intermediate in height and maturity are evaluated in comparison with the parents and the hybrids from which they were derived.

Materials and Methods

The material for the present study consisted of six groups of populations, the dwarf and early exotic parents (DE), late and tall Indian parents (TL), the three groups of crosses (F_1's) possible among them (DE × DE, DE × TL and TL × TL) and the productive intermediate selections (IS) derived from the exotic × Indian (DE × TL) crosses. The material, excepting the selections, was raised in a randomised complete block design with three replications during *kharif*, 1963. The selections (in F_6 and F_7 generations) were raised unreplicated during *kharif*, 1969. Data collected on five randomly chosen plants in each population on plant height (cm.), number of days to half—bloom and yield (gm/plant) were subjected to statistical analysis. The phenotypic and genotypic correlation coefficients were derived based on expectations. The correlation coefficients were partitioned into path coefficients following Dewey and Lu (1959).

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Results

The differences among the parental groups, DE and TL, and among their crosses were highly significant for all the characters including the comparisons, DE *vs.* TL and parents *vs.* hybrids (Table 1). Significant and positive phenotypic and genotypic correlations were observed in the DE and DE×DE groups for all pairs of characters except for plant height with days to half-bloom in the DE group (Table 3). On the other hand, the correlations between these characters though non-significant were negative in the case of TL and TL×TL groups except the one between plant height and yield. These associations agreed with the fact that the tall and late flowering (TL) parents were higher yielding than the dwarf and early flowering (DE) parents (Table 2).

Both the phenotypic and genotypic correlations between days to half-bloom and height, and days to half-bloom and yield were in opposite directions in DE×DE and TL×TL groups whereas the correlation between height and yield was positive in both the groups, the one in DE×DE being more than the one in TL×TL. The same observations were true for the parental groups, DE and TL also. But the non-significant and negative correlation between plant height and yield in the group DE×TL indicated that dwarf cultures isolated from this group would be capable of giving higher yields.

Table 1

Analysis of variance for some characters related to fitness and yield in different groups of sorghum

Source	DF	M.S.S.		
		Days to half-bloom	Plant height	Yield
Treatments	41	610·68	12428·28	2312·94
Parents	8	1453·09	19664·69	1642·30
DE	4	471·32	1279·98	394·80
TL	3	26·88	2690·78	236·50
DE vs TL	1	9658·78	144125·34	10849·66
Hybrids	32	416·16	9564·85	1449·94
DE×DE	8	438·62	1034·39	1227·31
DE×TL	18	30·38	3379·08	1221·37
TL×TL	4	199·86	1359·85	491·87
(DE×TL) vs (TL×TL)	1	3145·95	24859·90	1089·35
Rest	1	5316·04	206677·30	11538·20
Parents vs. Hybrids	1	96·27	46166·06	35294·30
Error	82	10·06	86·88	67·13

All m.s.s. are significant at 1% level.

TABLE 2

Yield, days to half-bloom and plant height in different groups of grain sorghum (means values)

Character	DE	DE×DE	DE×TL	TL×TL	TL	IS
Yield (gm./plant) (Y)	45·72	86·75	112·68	103·45	86·04	101·76
Days to half-bloom (X)	70·92	73·74	87·09	104·28	107·32	83·71
Plant height (cm.) (Z)	111·27	148·52	241·79	287·33	258·17	164·09

TABLE 3

Phenotypic and genotypic correlations between three important characters and the contributions to them through different paths of association in sorghum

Groups		r_{XZ}	P_{XY}	$P_{X\cdot Z\cdot Y}$	r_{XY}	P_{ZY}	$P_{Z\cdot X\cdot Y}$	r_{ZY}	P_{TY}
DE	P	0·7611	0·5517	0·3614	0·9131*	0·4749	0·4199	0·8948**	0·0713
	G	0·7971	0·5817	0·4403	1·0220**	0·5524	0·4636	1·0160**	–0·1557
DE×DE	P	0·8079**	0·7257	0·0912	0·8169**	0·1129	0·5863	0·6992*	0·1284
	G	0·8542**	0·7875	0·0670	0·8545**	0·0784	0·6727	0·7511*	0·2683
DE×TL	P	–0·4166	0·1932	0·0384	0·2316	–0·0921	–0·0805	–0·1726	0·9394
	G	–0·5157*	0·2997	0·0132	0·3129	–0·0255	–0·1546	–0·1801	0·9017
TL×TL	P	–0·6335	–0·6729	0·1334	–0·5295	–0·2105	–0·4263	0·2158	0·6823
	G	–0·6703	–0·7692	0·1851	–0·5841	–0·2762	0·5156	0·2394	0·6169
TL	P	–0·8891	–0·7677	0·3620	–0·4057	–0·4072	0·6826	0·2754	0·8006
	G	–1·1420**	0·5090	–1·0410	–0·5370	0·9115	–0·5813	0·3302	0·9699
IS	P	0·36**	0·0993	0·0807	0·18	0·2243	0·0357	0·26	0·9237

P=Phenotypic; G=Genotypic; T=Residual factors; *Significant at 5% level, **Significant at 1% level.

An analysis of the direct and indirect contributions of plant height and days to half-bloom to yield through path analysis makes the situation more clear. The direct effects of days to half-bloom and of height were high and opposite in direction in the DE, DE×DE and TL, TL×TL groups. In general, the percentage contribution of direct effects of days to half-bloom to yield was higher than that of height. On the other hand, the indirect effects of plant height *via* days to half-bloom on yield were considerable and positive. The position was reversed in the *IS* group.

These results suggest that the hybrid group DE×TL has acquired useful constellation of genes from both the parental groups which are markedly divergent in the important characters, days to half-bloom and height influencing fitness and yield. This statement derives further support from the observations that (a) the means of the DE×TL crosses and their derivatives (IS) were intermediate between those of DE and DE×DE on the one hand, and those of TL and TL×TL on the other, for days to half-bloom and height and (b) the mean yield of the DE×TL crosses was the highest followed by that of the TL×TL crosses (Table 2).

The residual effects were found to be high only in DE×TL, TL×TL, TL and IS groups (Table 3). This would imply that the role of related characters other than height and days to half-bloom was negligible in the DE and DE×DE groups. The size of the path coefficient due (Table 3) to residual effects in the selections (IS) and the DE×TL group indicated the importance of other characters and environmental effects which were felt more in tall parental group (TL) than in the dwarf parental group (DE).

Discussion

Prolonged natural selection in grain sorghums has resulted in the establishment of late and tall forms. The yield level of some of them is noteworthy at the single plant rather than at the population level; hybridization and selection among them did not markedly alter this situation which would imply that the genes for lateness and tallness were almost fixed under the continual action of natural selection. . On the other hand, artificial selection for relatively dwarf and early forms could establish types which were superior in yield and general performance at a population level only, especially under intensive cultivation. Hybrids between these dwarf populations also gave attractive yields. Thus two isolated divergent forms were produced by the forces of natural and human selection.

In these two groups of populations, association of characters influencing fitness is of a different nature and magnitude. Significant and positive association between plant height, days to half-bloom and yield was present in the dwarf-early parents in contrast to the negative association present in the tall-late parents. The association in the DE×DE and the TL×TL crosses were similar to those in DE and TL. From this, one can postulate that, to obtain an ideal combination, one should preferably deal with dwarf derivatives in which certain degrees of lateness and of tallness are incorporated and with tall derivatives in which certain degrees of earliness and of dwarfness are introduced. Relatively low correlations, intermediate in nature, obtained in the DE×TL crosses and the productive selections (IS) made from them support such a hypothesis. Such intermediate selections represent populations with little or no association between the characters examined.

The results from the path coefficient analysis have emphasized the point that the direct contribution of days to half-bloom to yield is more pronounced than and opposite in direction to that of plant height in the DE×TL crosses, indicating the significant role of days to half-bloom in determining the yield potential. But the direct contributions of days to half-bloom and plant height were positive in DE and DE×DE groups and negative in TL and TL×TL groups, in general. It, therefore, appears that the constellation of genes for these characters in the DE and the TL groups were altogether or at least functionally different. Strong associations between characters in those groups would limit recombination and hence selection advance in the crosses within the groups. But, in the crosses between the groups, the cryptic genetic potential would be released by recombination, thus making the selection of highly productive populations possible, as shown by the performance of the intermediate selections (IS), isolated from the DE×TL crosses.

The near absence of associations between important characters in the intermediate selections is encouraging in view of the observed positive association between maturity and yield (Dalton, 1967) and the pleiotropic and probably limited linkage effects of the genes governing height and maturity (Harinarayana *et al.*, 1971). In fact, these intermediate selctions represent 'intermediate productive peaks'; in other words, they represent selections in the intermediate range whose yield potential is much above that of some of the checks.

A hybridization programme involving negative assortative mating as in the case of DE×TL appears to be most desirable to obtain promising recombinants breaking the undesirable linkages which frequently limit the genetic advance (Falconer, 1967). Such mating results in the release of cryptic genetic variability and the redistribution of genetic variance (Murty, Arunachalam, Doloi and Ram, 1972). In sorghum, natural and human selection has resulted in establishing extreme forms as TL and DE. On this base, a system of negative assortative mating as in disruptive selection could help to produce intermediate but highly productive populations as revealed in this study.

Such intermediate populations with little or no association between most of the yield components offer considerable scope for improvement both under natural and artificial selection. This was demonstrated by the significant role played by the intermediate populations between wild and cultivated forms (disruptive selection in nature) in the evolution of cultivated sorghums (Doggett and Majisu, 1968). Productive intermediate populations between groups of cultivated sorghums widely differing in height and maturity could be exploited either for direct cultivation or as bridge populations or both. Such promising intermediate selections are, at present, in the process of release for general cultivation.

Summary

The nature of association between days to half-bloom, plant height and yield was examined in productive advanced generation selections and compared

with the dwarf-early and tall-late parents and their crosses. The correlations, both phenotypic and genotypic, were considerable in the parental groups and the within-group crosses, while they were low or negligible in intermediate selections and in the between group crosses.

The direct and indirect contributions of days to half-bloom to yield were more pronounced than those of the plant height. The direct effects were also of higher magnitude in the parental groups and their within group crosses. The vital role played by days to half-bloom in determining the yield potential was brought out.

Undesirable linkages and similar associations get dissipated in the intermediate selections from crosses between extreme forms. Thus, the intermediate selections, as revealed by correlations and path coefficients, have little or no association between yield components but have good yielding potential and represent 'intermediate productive peaks'. Some promising selections from such productive intermediate populations with no association between fitness components are in the process of release for general cultivation.

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