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PHENOTYPIC ADAPTABILITY OF CHARACTERS RELATED TO PRODUCTIVITY IN GRAIN SORGHUM, *SORGHUM BICOLOR*

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ABSTRACT

Ninety eight genotypes of grain sorghum, including 2 high-protein high-lysine lines, 2 local varieties, and 6 restorers of promising hybrids (CSH 1, CSH 4, CSH 5, SPH 1, CSH 7R) and CSH 8R along with 8 females and their 80 hybrids, were evaluated with respect to yield and its components at four locations. Significant genotype–environment interactions were observed in the material under investigation, for grain yield, 250-grain weight, and all the developmental characters except days to flower and number of primaries, secondaries/panicle, and panicle weight. Both linear and nonlinear components of genotype–environment interaction were significant, and the prediction of performance across environments was difficult for these traits. Stability of yield has been incorporated through stability for yield components. The released hybrid CSH 5 is suitable for kharif as well as rabi seasons. Hyhrids for different environments will have to be isolated to keep the total grain production stable.

Key words : Yield attributes, adaptability, line × tester, *Sorghum bicolor.*

There are several reports on the study of genotype–environment interaction with regard to high yielding sorghum hybrids and varieties developed after the advent of green revolution. However, there is no convincing report in the literature which could throw light on the nature and magnitude of genotype–environment interaction in the biometrical model, viz., the interaction of combining ability effects with four locations and stability of these effects. Therefore, the experimental material was selected from exotic germplasm, and Indian male parents and male sterile lines of newly developed hybrids. The present investigation is an attempt to estimate these interactions as described by Finlay and Wilkinson [1] and Eberhart and Russell [2].

MATERIALS AND METHODS

The materials and locations were same as reported earlier [3].

Observations were recorded on five random plants in each replication for plant height, days to flowering, number of whorls, primaries, secondaries, panicle length, breadth, panicle weight, fodder yield, and grain yield. The data were subjected to stability analysis by following the method of [2].

RESULTS AND DISCUSSION

Pooled analysis of variance (Table 1) showed that mean differences between genotypes were highly significant, revealing the presence of genetic variability among the genotypes studied. Highly significant mean squares due to environment plus genotype–environment interactions suggest that the genotypes interacted considerably with environmental conditions at different locations. A major portion of these interactions was attributable to linear component in respect of yield components and grain yield, whereas significant pooled deviation contributed more to the total interaction in case of secondaries/panicle. The pooled deviation was significant for all the components, except days to flower. Since pooled deviation SS was significant due to high deviation SS of all the parents and hybrids, the significance of deviation in regression slope from unity for each genotype was tested against standard error and worked out from its own residual as suggested by [4].

Table 1. Analysis of variance for stability parameters for eight selected characters of 18 parents and 80 hybrids over four environments

Source of variation	d.f.	Days to 50% flowering	Panicle length	Primaries per panicle	Secondaries per panicle	Panicle weight	Grain yield per plant	Fodder yield per plant	250-grain weight
Genotypes (G)	97	124.3**	46.9**	232.5**	15685.7**	1932.1**	424.7**	43443.6**	3.4**
Environments (E)	3	73.6**	165.4**	332.5**	16318.9**	11177.7**	14016.6**	22539.4**	9.6**
G × E	291	17.8**	3.9**	43.7**	5062.6**	133.9	88.2**	2198.1**	0.4**
E (linear)	1	111.9**	496.0**	987.6**	48909.8**	3353.0**	42042.9**	67616.5**	28.7**
G × E (linear) (M-2)	97	16.0	14.2*	42.3**	8757.8**	296.8**	192.6**	3840.6	0.8**
Pooled deviation (M-3)	196	18.6	3.7**	44.1**	3184.9**	51.8**	35.6**	1363.2**	0.3**
Pooled error	776	1.2	2.9	18.0	3681.7	1213.2	26.4	567.2	0.3

*, **Significant at 5% and 1% levels, respectively.

Mean grain yield and two stability parameters for 18 parents and selected hybrids of sorghum are presented in Tables 2 and 3. In general, the hybrids with two Ethiopian lines and two Wani varieties were poor yielding, while those with CS 3541, IS 3924 and PD 3-1-11 were better yielding. The parents 2077 B (61.56 g), PD 3-1-11 (70.20 g), and IS 3924 (24.15 g) showed grain yield/plant, while hybrids 3660A × PD 3-1-11 recorded 68.35 g grain yield. Among the hybrids involving CS 3541, hybrids CSH-5 (2077A × CS 3541) and CSH-6 (2219A × CS 3541) are promising. The Ethiopian lines were tall and late, producing purple shrivelled grains, while the Wani varieties were chalky and mid-late in maturity.

Samuel et al. [6] and Paroda and Hayes [5] emphasised that linear regression could simply be regarded as a measure of response of particular genotypes, whereas

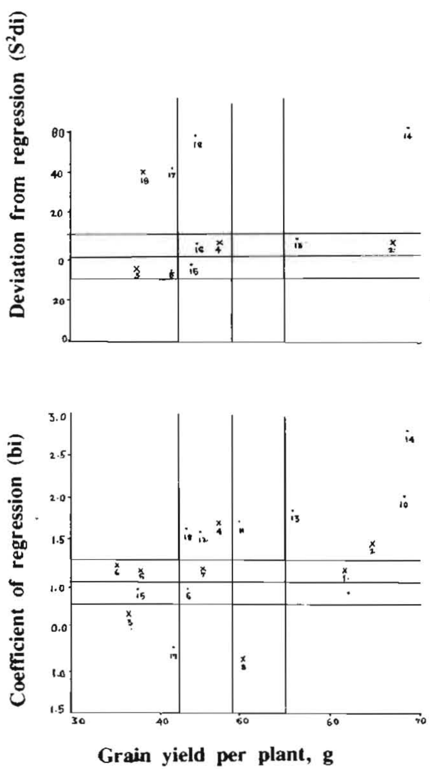

Fig. 1. Stability of 18 parents for grain yield per plant.

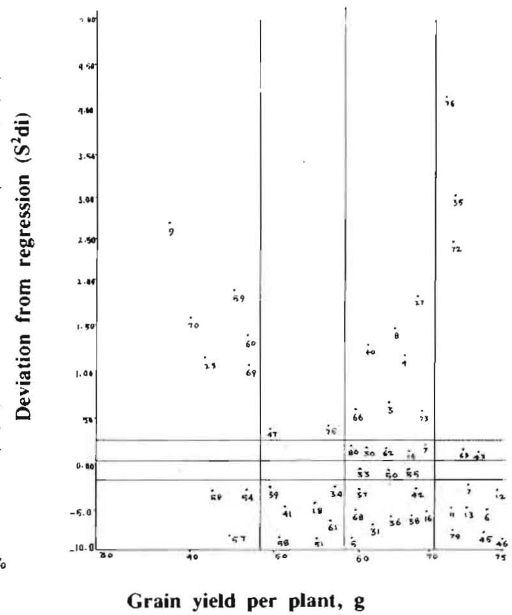

Fig. 2. Stability of 80 hybrids for grain yield per plant.

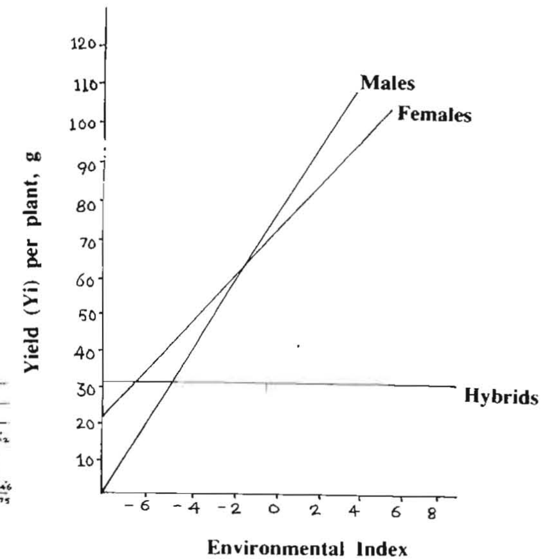

Fig. 3. Stability of females, males and hybrids.

Table 2. Estimates of stability parameters of parent varieties of sorghum

Variety	Days to 50% bloom			Panicle length			Primaries/panicle			Secondaries/panicle		
	m̄	b̄i	S^2di	m̄ (cm)	b̄i	S^2di	m̄	b̄i	S^2di	m̄	b̄i	S^2di
Females:												
1036 B	67.7	1.13**	0.9	24.5	2.2**	8.6**	78.2	2.0**	25.6**	534.0	2.5**	3900.9**
2077 B	74.6	0.3**	30.03**	30.9	0.5**	9.1**	58.8	−1.8**	14.0	465.0	0.8**	2215.6**
2219 B	60.5	0.9**	5.02	24.5	2.1**	1.9**	53.5	1.5**	10.0**	335.0	0.3**	−1125.1**
36 B	67.3	1.0	3.1**	18.8	2.0**	0.6	62.2	−1.5**	47.2**	393.0	0.6**	1509.2**
3660 B	67.8	1.1	5.07**	21.9	1.1	−0.7	58.2	−0.2**	−4.3**	371.6	−0.2**	−964.2**
1202 B	64.2	1.4**	32.72**	21.2	0.9	2.1**	58.0	−0.6	4.6**	371.3	0.1**	87.5**
1258 B	62.4	1.2**	13.88**	22.9	0.8	0.3	56.2	0.3**	31.8**	371.6	−1.0**	1332.0**
111 B	72.2	0.6**	4.50**	24.5	0.5**	·1.0**	50.8	1.1	−4.5**	345.0	0.9**	−607.6**
Males:												
IS 84	65.9	0.7**	3.5**	28.1	0.9	0.6	49.4	1.0	35.2**	312.2	−0.1**	−1042.2**
IS 3924	66.6	0.9.	8.0**	26.6	0.8	−0.5	58.6	−0.1**	−3.5**	387.6	−0.2**	499.5**
370	60.9	1.0	28.4**	30.8	0.5**	−0.8	−61.1	−0.8	27.4**	437.7	−0.3**	821.7**
CS 3541	66.9	1.4**	0.8	22.2	0.8	0.1**	44.4	−1.6**	12.8**	305.0	1.0	7841.9**
168	65.8	1.0**	2.4**	19.9	2.2**	1.5**	59.2	1.3	62.4**	426.6	2.0**	−422.2**
PD 3-1-11	70.6	0.8**	1.9**	27.3	1.3	3.5**	78.1	−3.3**	87.5**	451.8	−1.6*	420.0**
IS 11758	85.8	1.1**	17.9**	21.9	−2.2	2.5**	53.5	3.3**	89.3**	349.6	−0.1	1289.2**
IS 11167	86.9	1.3**	7.1**	22.8	1.2*	16.2**	54.1	3.7**	170.3**	387.4	−0.0**	5299.1**

*, **Significant at 5% and 1% levels, respectively.

the deviation around the regression line (S^2di) is the most suitable measure of stability, genotypes with the lowest standard error (Sb) or deviation around the regression line (S^2d) being the most stable and vice versa. Accordingly, it was possible to judge the stability of genotypes and due consideration was also given to their mean performance and linear response.

GRAIN CHARACTERS

Out of the 98 genotypes, 6 had significant S^2d for grain yield (Table 2, Fig. 1). None of the parental lines indicated average stability for grain yield (Fig. 2). However, for 250-grain weight, lines 3660 B, 1202 B, and PD 3-1-11 exhibited average stability. Cross 2219A × 168 and the released hybrids CSH-6 and CSH-4 showed above average stability, although S^2d values were high for grain yield in these released hybrids. Crosses 2219A × PD 3-1-11 and 36A × PD 3-1-11 (CSH-8R) indicated average stability for grain yield, while the released hybrids CSH-5 and CSH-7R had a regression slope indicating their suitability for high yielding environments. The male parent PD 3-1-11 exceeded the corresponding hybrids in yield level (Fig. 3). Hybrid CSH-7R showed highest deviation, whereas CSH-5 had the minimum S^2d values. The performance of CSH-7R, a winter season hybrid, was unpredictable under the present set of environments, particularly when sown in kharif at three locations and in rabi at one location. On the other hand, CSH-5 would be the best choice for all environments and seasons, as also reported by [9]. For 250-grain

for selected characters over four environments

Panicle weight			Grain yield/plant			Fodder yield/plant			250-grain weight		
m⁻ (g)	bi⁻	S^2di	m⁻ (g)	bi⁻	S^2di	m⁻ (g)	bi⁻	S^2di	m⁻ (g)	bi⁻	S^2di
63.0	0.7**	0.3	58.9	1.3**	−3.1	141.1	1.1**	1437.0**	5.9	4.3**	0.1
66.2	0.8	0.6*	61.6	1.7**	4.7**	152.7	1.7**	1068.7**	5.6	3.6**	−0.1
50.7	0.5**	0.1	36.3	0.4**	−5.0**	99.9	1.0	1528.7**	6.1	1.8**	−0.1
54.3	0.8	6.1**	48.4	1.4**	2.3**	123.0	1.4**	1334.0**	7.6	3.0**	0.1
59.1	0.7*	7.8**	42.8	1.0	−6.0**	131.6	1.2**	1631.9**	5.9	0.9	0.0
61.9	0.9	82.2**	38.6	1.3**	29.7**	83.3	0.3**	−63.8**	6.1	1.0	0.4
62.3	0.8	69.2**	44.2	1.1**	−6.2*	83.6	0.5**	−108.4**	6.0	1.2**	0.1
65.0	0.8	11.2**	49.0	1.1**	−5.1**	75.9	0.5**	−53.2**	6.4	1.9**	0.2
56.7	0.8	−53.7**	35.7	0.8**	−1.9	69.7	0.6**	98.7**	7.0	1.5**	0.2
72.1	1.1	0.9	64.1	1.8**	2.3**	151.5	1.3**	31.5**	8.2	2.3**	0.2
67.7	0.9	1.2**	49.1	1.7**	4.1**	113.0	0.8**	49.4**	5.8	0.7**	−0.1
61.1	0.7**	1.3**	43.3	1.5**	8.7**	88.0	0.5**	−94.6**	6.3	1.9**	0.1
74.3	1.1	0.0	55.0	1.8**	10.0**	115.3	1.1**	2.6**	6.6	3.5**	0.0
84.5	1.3**	1.5**	70.2	2.8**	65.4**	162.9	1.3**	15.7**	6.7	1.1	−0.0
55.1	−0.0**	1280.2**	41.0	0.5**	409.1**	277.3	0.0**	28.1**	5.4	1.1**	4099.0**
59.6	−0.0**	5299.1**	42.6	0.2**	399.6**	369.7	0.0**	52.7**	5.9	0.8**	2829.6**

weight, crosses like 2219A × IS 11167, 1202A × 370, and 111A × PD 3-1-11 exhibited average stability.

DEVELOPMENTAL CHARACTERS

Among the developmental characters, days to flowering is the most important trait for seed production. The females, viz., 2077B, (female of CSH-5) and 1202B (female of Maldandi hybrid), and males like No. 370 and IS 11758 showed steep regression slope S^2d, indicating that these strains flower very differently in different environments, while 36B, 3660B, IS 3924, and 370 exhibited average stability for flowering. For the remaining developmental characters none of the parents showed average stability, except 168 for fodder yield. Among hybrids, those of ♀ 1036B, 2219B and 1258B with ♂ PD 3-1-11, 370, Wani and Ethiopian lines, 168 and IS 84, showed average stability for flowering and number of leaves, for other characters none of the crosses indicated average stability, considering their bi and S^2di values. Thus, the stable parents gave rise to stable hybrids, though in some crosses even unstable parents produced hybrids with average stability.

Rana and Murty [8] reported that the stable genotypes had regression coefficient around unity for flowering and early vigour, and concluded that there was predictable response for flowering and early vigour with improvement in environment. Singh and Nayeem [9] found male line 168 and female line 1202B stable for most of the developmental and growth characters. In the present study also, stable males, females

Table 3. Estimates of stability parameters of selected hybrids

Hybrid	Days to 50% bloom			Panicle length			Primaries/panicle			Secondaries/panicle		
	m⁻	bi⁻	S^2di	m⁻ (cm)	bi⁻	S^2di	m⁻	bi⁻	S^2di	m⁻	bi⁻	S^2di
1036A × IS 3924	64.7	0.5**	34.7**	30.4	0.7**	−0.9	69.9	−0.0**	13.8**	520.9	2.9	4804.9**
1036A × CS 3541	63.8	0.9	41.7**	27.7	1.9**	−0.5	66.6	3.4**	−5.4**	438.1	1.9**	,2733.1**
1036A × PD 3-1-11	65.4	1.2**	0.8.	29.5	0.8	1.8**	74.4	−0.1	0.2	497.7	2.3**	−104.8**
1036A × IS 11758	74.1	1.0*	18.9**	29.9	−0.4**	3.9**	69.0	3.3	26.0	457.5	0.7**	5938.8**
2077A × CS 3541	65.4	0.6**	1.2*	30.2	0.8*	−0.7	60.6	−0.2**	15.2**	430.7	0.5**	4120.3**
2077A × IS 11758	72.1	0.5*	5.8**	27.4	0.3**	1.9**	68.1	3.5**	15.2**	508.1	1.9**	−909.1**
36A × CS 3541	60.3	1.0	10.0**	21.3	0.9**	−2.1	58.8	2.2**	13.0**	441.3	1.2	8723.3**
36A × PD 3-1-11	62.8	0.8**	3.0**	24.3	0.9	−0.4	71.8	2.0**	13.0**	445.3	0.8	1294.0**
36A × IS 11758	74.6	1.1**	16.5**	24.2	0.2**	1.1**	71.7	3.5**	17.2**	472.4	0.3	3458.8**
36A × 168	63.2	0.5**	21.9**	20.7	0.6**	0.6	72.4	−1.9**	18.4**	595.4	1.1	1310.4**
3660A × CS 3541	62.4	1.0	6.7**	25.4	1.0**	0.8	53.0	−1.1	25.3**	407.1	0.4**	−436.3**
3660A × IS 11758	65.2	1.2**	91.2**	28.4	1.6**	1.7**	64.4	2.4**	−3.4**	471.3	0.0**	3166.1**
1202A × CS 3541	60.3	1.0	10.4**	26.8	1.6**	8.7**	50.6	−1.0**	4.8**	402.9	2.7**	532.7**
1202A × IS 11758	73.5	1.1**	0.1**	27.0	0.9**	8.7**	67.8	2.4**	−5.6**	454.5	0.3**	1267.3**
1258A × CS 3541	61.4	1.1**	7.8**	27.2	0.6**	0.6	52.5	−1.0	53.2**	440.6	0.8*	14731.1**
1258A × IS 11758	72.7	0.8**	39.5**	25.8	0.4**	0.7**	66.2	1.3	17.3**	428.9	1.3**	155.2**
2219A × CS 3541	60.4	1.0	10.0**	27.5	−0.6**	0.8	53.0	3.3**	4.5**	383.1	2.6**	−1190.8**
2219A × IS 11758	70.7	0.4	11.8**	28.9	0.7**	−0.9	76.0	1.5**	48.9**	516.6	2.7	2063.8**

*, **Significant at 5% and 1% levels, respectively.

and their hybrids have been isolated for flowering only, while for remaining characters the parents and hybrids behaved differently.

PANICLE CHARACTERS

Females like 3660B (bi = 1, 0; S^2di = 0.66) had average stability for panicle length, but none of the female lines showed average stability for other characters. Among males, IS 84 for panicle length, 168 for number of whorls, and IS 3924 and 168 for panicle weight showed average stability.

Average stability for panicle length in sorghum has been reported earlier [8]. The only hybrids with average stability were 2219A × PD 3-1-11, 36A × PD 3-1-11, and 1258A × 168 for panicle length; 1036A × CS 3541 and 2219A × 370 for panicle breadth; 2077A × 370, 3660A × IS 11758, 111A × IS 11758, 1202A × W5, and 111A × 168 number of whorls; and 1036A × for panicle weight.

Rana and Murty [8] found var. Kafir and Dochna adapted for panicle length for all environments, none of the varieties adapted for number of primaries, and two Indian types (BP 53 and PJ 4K) adapted only to rich environments. None of the parental lines used by us indicated average stability for panicle breadth, number of primaries and secondaries.

Similarly, none of the hybrids showed average stability for number of primaries and secondaries. However, for panicle breadth and number of whorls, some crosses exhibited average stability, indicating heterozygote advantage for these traits. It is noteworthy that the released hybrids CSH 5, CSH 6 and CSH 7R gave below average and hybrid CSH 8R above average stability for number of whorls and primaries.

for eight characters over four environments

Panicle weight			Grain yield/plant			Fodder yield/plant			250-grain weight		
m (g)	bi	S^2di	m (g)	bi	S^2di	m (g)	bi	S^2di	m (g)	bi	S^2di
101.2	2.8**	4804.9**	60.5	1.3**	1.0**	149.3	0.4**	45.2**	7.3	0.4**	801.2**
90.3	1.8**	2733.0**	63.7	1.3**	1.6**	157.5	1.5**	71.8**	6.4	0.3**	1789.6**
98.1	2.3**	−104.7**	68.4	1.1	2.6**	200.0	1.3**	6.6**	9.1	0.8**	2253.6**
60.1	0.6**	5938.8**	39.4	0.5**	206.2**	345.6	−0.1**	243.9**	7.3	0.6**	1280.3**
93.7	0.5**	4120.3**	64.5	1.3**	0.8	124.3	1.6**	1.7**	6.6	0.0**	−160.3**
160.8	1.9**	−909.1**	36.4	1.0	12.1**	466.0	0.8**	−7.9**	8.1	0.8**	896.3**
94.4	1.1	8723.3**	58.1	1.1	0.9**	165.6	1.0**	−4.1	−4.1	0.9	162.2**
163.5	0.8	1294.0**	65.3	1.2	41.2**	174.3	1.0*	4.4**	8.4	1.7**	498.3**
91.2	0.3**	3458.8**	51.6	1.0	20.1**	366.6	0.3**	−5.8**	9.4	0.4**	5526.1**
111.7	1.1	1310.4**	74.2	1.1	1.5**	166.8	1.5**	227.7**	8.2	1.1**	155.4**
87.1	0.3**	−436.3**	64.2	1.2*	4.7**	160.9	1.6**	−6.0**	6.3	0.7**	111.0**
98.6	0.0**	3166.1**	66.9	1.2	−5.1**	362.2	0.2**	5.6**	8.4	0.3**	1266.9**
79.8	2.7**	532.7**	47.7	1.2	−92.8**	134.4	1.3**	−5.8**	7.1	0.5**	−101.3**
67.4	0.3**	1267.3**	45.6	0.5**	6.6**	381.4	0.5**	139.7**	8.4	1.0	6494.9**
151.9	2.3**	−1190.8**	36.6	0.5**	0.9**	108.7	0.5**	2.9**	6.1	0.3**	−52.8**
178.8	2.6**	2063.8**	59.6	1.1	29.1**	253.4	1.6**	25.1**	8.3	1.1**	3565.1**
82.8	−0.8*	14731.1**	54.7	0.8	1.8**	147.9	0.3**	16.8**	7.5	0.7*	1168.2**
62.1	1.3**	155.1**	46.1	0.4**	5.6**	415.6	−0.4**	39.6**	9.1	3.1**	337.2**

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