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Phenotypic Stability of Yield Components in Pearl Millet

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ABSTRACT

Genotype-environment ($g \times e$) interactions were studied for six component characters by growing six females, 16 males, their 96 hybrids and three hybrid checks in three environments. Pooled regression analyses indicated that $g \times e$ interaction was present with a higher proportion of $g \times e$ (linear) in case of days to earing and ear length whereas non-linear portion for plant height in both parents (homozygous)and hybrids (heterozygous). For ear bearing tillers, seed size and ear weight non-linear portion was higher in parents whereas both the components were at par in hybrids. There was differential behaviour of both the population over environments. Utility of individual regression analysis was evident for the study of $g \times e$ interaction. None of the females in hybrid-combinations was better responsive and stable for all the component characters studied. 23 D_2 A was good combiner for better responsiveness for ear weight, seed size and plant height. 5054A was good combiner for low non-linear responsiveness for ear length and days to ear emergence.

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INTRODUCTION

The extensive use of pearl millet *Pennisetum typhoides* (Burm. f.) Stapf and C. E. Hubb. hybrids in India has increased the importance of performance of hybrids *per se*. It is necessary to have the information on stability of yield and its component characters, which is meagre in this crop. In an earlier study (Pethani and Kapoor, 1985a) results obtained from stability analysis in respect of grain yield were reported. In the present paper results on stability parameters in parents (homozygotes) and their hybrids (heterozygotes) for component characters viz., days to ear emergence, plant height, ear bearing tillers, ear length, 500 grain weight and ear weight are presented.

MATERIALS AND METHODS

The material consisted of six females (five male sterile and an open pollinator tester), sixteen inbreds (used as male) and their 96 F_1 hybrids along with 3 checks. Each entry was sown in a 11 x 11 simple lattice design. Three experiments were laid out, two at Hissar (E_1 and E_2 with 4 and 2 replications respectively) in Haryana and one at Kodinar (E_3 with 4 replications) in Gujarat. E_2 was with delayed sowing and medium fertility

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level. Each entry was sown in a single row plot of 3 m length, 60 cm apart. The distance between the plants was 20 cm. Five plants at random were selected for recording data on days to ear emergence, plant height (cm), ear bearing tillers, ear length (cm) and ear weight (g). Average values were used as mean for the computational purposes. Individual values of 500 grain weight (g) of composite sample of five plants were used for the analysis. The genotype-environment interaction was worked out following Eberhart and Russell (1966).

RESULTS AND DISCUSSION

The pooled analysis of variance showed significant differences between the genotypes for all the characters studied (Table 1). Higher genotypic differences among hybrids were observed for plant height, ear bearing tillers and 500 grain weight indicating better heterotic response for these characters, whereas for days to ear emergence, ear length and ear weight higher genotypic differences among parents were observed. The mean squares due to environments (linear) were maximum for most of the characters (except ear length) indicating that larger differences between environments alongwith the greater part of varietal response was a linear function of environments and thus these characters were influenced by environments considerably. The environmental response was low for ear length. The genotype-environment ($g \times e$) interaction sum of squares were partitioned into that of linear (predic-

TABLE 1

Pooled analysis of variance (mean squares) of 22 parents (P) and 99(96+3 checks) hybrids (H) of pearl millet over three environments.

Source		*Genotypes*	*Environments (linear)*	*Genotypes x environments (linear)*	*Pooled deviation (non-linear)*	*Pooled error*
df	*(P)*	*21*	*1*	*21*	*22*	*147*
	(H)	*98*	*1*	*98*	*99*	*686*
Characters						
Days to	(P)	27.21**	487.63**	10.83**	4.67**	1.53
earing	(H)	24.64**	1487.94**	7.74**	4.97**	0.98
Plant	(P)	726.9**	26461.0**	178.2**	520.8**	50.0
height	(H)	774.7**	168197.0**	167.1**	273.0**	21.3
Ear	(P)	2.78**	9.16**	0.44**	0.92**	0.30
bearing	(H)	3.28**	173.63**	0.95**	0.93**	0.35
tillers						
Ear	(P)	82.95**	10.16**	6.14**	5.63**	2.61
length	(H)	58.70**	55.86**	10.80**	5.50**	1.54
500	(P)	0.311**	3.557**	0.131**	0.143**	0.070
grain	(H)	0.881**	37.420**	0.116**	0.117**	0.051
weight						
Ear	(P)	856.6**	5557.1**	300.5**	361.0**	23.36
weight	(H)	696.3**	53973.4**	318.1**	310.4**	66.3

**Significant at the 1 per cent level

table) and pooled deviation (non-linear) components. Both these components were significant for all the characters (Table 1). Evidently there were significant differences among genotypes as far as their stability behaviour was concerned. The variance due to *g x e* (linear) was higher for parents as compared to hybrids in case of days to earing, plant height and 500 grain weight, whereas in hybrids it was higher for ear bearing tillers, ear length and ear weight. The mean square due to *g x e* (linear) was higher than pooled deviation both in parents as well as in hybrids for days to earing and ear length. In case of ear bearing tillers non-linear portion for seed size and ear weight was higher in parents whereas in hybrids both the portions were at par. Higher proportion of mean square due to pooled deviation was observed for plant height in both the populations. This revealed the differential behaviour of both the populations over environments. Such differential behaviour among parents and hybrids was reported for downy mildew disease incidence, grain and fodder yield in this material by Pethani *et al.* (1980), Pethani and Kapoor (1985 a; b).

The study of *g x e* interactions leads to meaningful evaluation of individual genotypes for yield and its component characters which could be used in future breeding programmes. In judging the phenotypic stability in addition to both the linear (b) and non-linear ($\bar{S}^2d$) components of *g x e* interactions due consideration also should be given to mean performance of individual genotypes.

In case of days to ear emergence three females, six males and 31 hybrids showed neither significant regression mean square (m.s.) nor significant remainder m.s. indicating complete absence of *g x e* interaction (Table 2). Two females, seven males and 31 hybrids exhibited significant regression m.s. and non-significant remainder m.s. indicating that linear regression accounted for whole of *g x e* interaction and prediction of performance of these genotypes would be perfect and reliable. One female, three males and 37 hybrids had significant remainder m.s. while their regression m.s. was non-significant, which make their performance unpredictable under environmental changes. Considering the individual parameters of stability ($\bar{X}$, b, $\bar{S}^2d$), it is evident that among parents 5071A, 5054A, M 64 P_2, H 153, H 46 and hybrids 5054A x H 66, 5054A x H 232, 5094A x H 232, were early to ear emergence alongwith high stability but varying level of responsiveness for days to ear emergence (Table 3). H 130-2 was the most earliest but was unstable ($\bar{S}^2d$ significant).

For plant height one female, five males and 23 hybrids showed absence of *g x e* interaction as they had non-significant linear regression and deviation from regression m.s. (Table 2). Two females, three males and 27 hybrids exhibited significant predictable portion (only b significant) revealing thereby that linear regression alone accounted for most of *g x e* interactions. Three females, eight males and 49 hybrids showed presence of only non-linear portion of *g x e* interaction (only $\bar{S}^2d$ significant). Among the parents HC 73-1 was the tallest with significant non-linear g x e interaction (Table 3). Except H 49 and H 130-2 rest of the paernts had unit or above unit responsiveness. Among ten tallest hybrids most of the crosses were with

HC 73-1 as one of the parent, and showed unit or above unit responsiveness.

For ear bearing tillers complete asbence of *g x e* interaction was indicated in respect of many genotypes (four males, 13 females and 61 hybrids) (Table 2). Linear regression alone accounted for almost all the *g x e* interaction for one male and 16 hybrids. Presence of only non-linear portion of *g x e* interaction was indicated by two females, two males and 22 hybrids. A simultaneous consideration of the adaptation parameters (Table 3) showed that among parents H 49, H 47-1, H 206 and among hybrids 5094 A x H 130-2, 5094 A x C-6 and 5071 A x M 64 P_2 were with high tillering and stable genotypes but with low responsiveness ($b < 1$) to environmental changes. The crosses 23 D_2 A x H 112, 5094 A x M 64 P_2, 5094 A x H 112 and parents H 130-2 and H 46 were not only stable with high ear bearing tillers but were also highly responsive ($b > 1$) indicating high tillering potentiality in favourable environment while crosses 5054 A x H 130-2 and 5054 A x H 46 and parents M 64 P_2 and C 6 genotypes were unstable for ear bearing tillers.

For ear length as many as two females, eleven males and 69 hybrids showed absence of *g x e* interactions. In respect of two females, three males and ten hybrids only linear portion accounted for almost all the *g x e* interactions. Lastly two females, two males and 20 hybrids showed existence of only non-linear portion of *g x e* interaction. Highest ear length was expressed by HC 73-1 followed by 126 D_2 A, but former was stable while the later was unstable, but both had negative b values indicating favourable environment would tend to reduce the length of ear in these genotypes. Hybrid 126 D_2 A x H 206 and HC 73-1 x H 138 had longest ear with average responsiveness and high stability. The crosses HC 73-1 x H 206 also showed greater ear length but was unstable with high responsiveness.

In case of 500 grain weight, one female, 13 males and 66 F_1 hybrids

TABLE 2

Evaluation of parents and F_1 hybrids of pearl millet on the basis of individual *g x e* interaction components.

Character	*Predictable*						*Unpredictable*		
	g x e absent (both b and $\bar{s}^2d$) non-significant)			*g x e present (only b significant)*			*g x e present (only $\bar{s}^2d$) significant)*		
	♀	♂	F_1	♀	♂	F_1	♀	♂	F_1
Days to ear emergence	3	6	31	2	7	31	1	3	37
Plant height	1	5	23	2	3	27	3	8	49
Ear bearing tillers	4	13	61	–	1	16	2	2	22
Ear length	2	11	69	2	3	10	2	2	20
500 grain weight	1	13	66	1	3	13	4	–	20
Ear weight	–	4	43	2	4	21	4	8	35

♀ = Females; ♂ = Males

exhibited absence of *g x e* interaction. The overall mean of all the genotypes also showed similar response and hence these genotypes could be regarded to possess high ecovalence i.e. wide ecological range for seed weight. One female, three males and 13 hybrids had only the linear portion of *g x e* interaction as significant. Still another set of four females and 20 hybrids exhibited the presence of only non-linear portion of regression variance. As in ear length the genotypes HC 73-1 and 126 D_2 A possessed high grain weight though the former was stable while the latter was unstable (significant $\bar{S}^2d$). But HC 73-1 was highly responsive (b= 2.32) while 126 D_2 A was less responsive (b = 0.28) to changing environment. Most of the hybrids with higher grain weight were stable and showed unit responsiveness. The most significant aspect with regard to seed weight performance in hybrids was that 126 D_2 A was involved as female parent in all the best hybrids which indicated the existence of maternal effect for seed weight. These hybrids not only showed high mean performance but were also highly stable with desired level of responsiveness.

For ear weight complete absence of *g x e* interaction was indicated in respect of four males and 43 hybrids as evident from their non-significant b and $\bar{S}^2d$ values (Table 2). Linear regression alone accounted for almost all the *g x e* interaction in respect of two females, four males and 21 hybrids. For the remaining genotypes i.e. four females, eight males and 35 hybrids only the remainder m.s. was found to be significant which would make their performance unpredictable under environmental changes. The genotypes 5054 A, 5094 A and H 284 were found to possess high mean value and high responsiveness ($b > 1$) but they were unstable (significant $\bar{S}^2d$) whereas M 64 P_2 and H 49 were found to possess high mean responsiveness and stability. The hybrids 5071 A x M 64 P_2, 23 D_2 A x H 49 and 23 D_2 A x H 112 showed high stability and responsiveness to improvement in the environment (Table 3).

The most important practical aspect of these studies would appear to be the existence of *g x e* interaction and the proportion of this interaction which is due to linear response. On looking to the *g x e* interaction of individual genotypes summarised in Table 2 it is interesting to note that in majority of the genotypes response was predictable across environments where there was no *g x e* interaction or even if interaction existed it was due to linearity. Such a prediction, of course, becomes impossible if the nonlinear component of *g x e* interaction is predominant (Table 1 and 2). The utility of individual regression analyses for the study of *g x e* interaction was, therefore, evident. The data presented in Table 1 and 2 reveals that though a large proportion of genotypes had predictable behaviour for all the characters studied, they were however, somewhat different in their stability parameters and these component characters, therefore, are likely to be easily handled in breeding programme.

On comparing the performance of various females in hybrid combinations with regard to unit or more than unit linear response, none of the females was good combiner for better responsiveness ($b \geqslant 1$) for all the characters studied. Maximum number of hybrids with better responsiveness were

TABLE 3

Stability parameters of best 10 parents and hybrids of pearl millet.

	Days to earing				*Plant height (cm)*				*Ear bearing tillers*		
Parents	$\bar{X}$	*b*	S^2d	*Parents*	$\bar{X}$	*b*	S^2d	*Parents*	$\bar{X}$	*b*	S^2d
1 H 130-2	47.1	0.96	25.5**	HC 73-1	211.1	1.27	1074**	M 64 P_2	6.40	2.67	10.5**
2. 5071 A	50.3	0.69	2.5	H 49	210.1	0.58	18	C 6	4.76	2.36	1.6*
3. 5054 A	50.4	1.15**	–1.5	H 138	200.6	1.15**	–2	H 49	4.38	0.13	0.1
4. H 49	50.9	1.61	13.4**	H 284	196.8	1.08*	–13	H 47-1	4.31	0.55	0.0
5. M 64 P_2	51.7	1.01	3.0	H 232	194.7	1.29	22	H 206	4.27	0.25	0.0
6. H 153	52.0	1.11*	–1.1	H 192-2	193.7	1.48	453**	H 153	4.25	–1.29	0.2
7. H 46	52.1	1.15**	–1.4	H 206	193.3	0.95	396*	H 130-2	4.15	1.68	0.5
8. 5094 A	52.7	0.87	2.4	H 66	192.1	1.12**	–1	H 46	3.90	1.73**	0.3
9. H 47-1	52.9	0.96	2.6	H 153	187.6	1.12	22	5071 A	3.73	2.20	0.2
10. H 92-2	53.0	1.23**	0.4	H 130-2	184.7	0.60	446**	5054 A	3.70	0.01	0.3
Hybrids				Hybrids				Hybrids			
1. 5094 A x H 130-2	47.2	0.54	10.5**	HC 73-1 x H 482	229.3	1.62	43	5094 A x H 130-2	7.86	0.68	0.2
2. 5054 A x H 66	47.7	1.43*	0.7	HC 73-1 x H 49	220.8	0.81	285**	5094 A x C_6	6.63	0.69	0.2
3. 5054 A x H 232	48.0	2.47*	1.9	HC 73-1 x H 284	223.5	1.05	44	5071 A x M 64 P_2	6.52	0.06	0.6
4. 5094 A x H 232	48.1	0.63*	–0.9	HC 73-1 x H 138	221.0	0.94	3035**	23 D_2A x H 112	6.46	1.89	1.0
5. 5094 A x H 192-2	48.3	1.54	2.0	HC 73-1 x H 92-2	218.7	0.77	164**	5094 A x M 64 P_2	6.30	1.74*	–0.3
6. 5054 A x M 64 P_2	48.4	1.71	2.1	HC 73-1 x C 6	217.2	0.59	15	5094 A x H 46	6.20	0.28**	–0.4
7. 5054 A x H 130-2	48.4	1.17	0.5	HC 73-1 x H 232	216.3	1.43**	–21	5094 A x H 112	6.19	1.37**	–0.3
8. HC 73-1 x H 66	48.6	0.99	1.5	126 D_2A x H 130-2	215.9	1.10	23	5094 A x H 49	5.88	0.83	1.2
9. 23 D_2A x H 130-2	48.9	0.50**	–1.0	126 D_2A x H 232	215.3	0.78*	–16	5054 A x H 130-2	5.68	–0.61	1.3*
10. 5094 A x H 153	48.9	-0.68	30.00**	23 D_2A x H 232	214.8	1.15	31	5054 A x H 46	5.65	1.46	1.5*

(*Table 3 contd.*)

Parents	Ear length (cm)			Parents	500 grain weight (g)			Parents	Ear weight (g)		
	$\bar{X}$	*b*	$\hat{S}^2d$		$\bar{X}$	*b*	$\hat{S}^2d$		$\bar{X}$	*b*	$\hat{S}^2d$
1. HC 73-1	41.1	–5.75**	–2.6	HC 73-1	3.97	2.32**	–0.11	5054 A	96.1	2.18	3094**
2. 126 D_2A	36.9	–2.50	8.3*	126 D_2A	3.63	0.28	0.42*	M 64 P_2	84.5	2.05**	–8
3. 5054 A	34.5	1.80	–0.3	H 130-2	3.61	1.58	0.07	5094 A	84.0	1.90	780**
4. 5094 A	33.7	0.26	1.8	H 206	3.61	0.72*	–0.11	H 49	81.1	1.96**	–23
5. H 49	29.0	5.05	–1.8	H 46	3.57	0.75	0.02	H 284	68.6	2.23	682**
6. H 206	27.5	0.02	24.2**	C 6	3.49	1.94	0.05	H 46	68.3	1.00	184**
7. H 66	26.7	–0.61	0.9	M 64 P_2	3.31	1.06	0.05	5071 A	60.5	0.80	349**
8. H 92-2	25.7	1.82	1.6	H 153	3.27	1.03	0.08	H 47-1	52.1	1.47	7
9. H 130-2	25.2	1.76	0.2	H 232	3.24	0.86	0.07	H 112	44.8	1.36*	–23
10. H 284	25.1	0.26	10.4*	H 112	3.24	1.66**	–0.08	H 138	37.9	0.35	9
Hybrids				Hybrids				Hybrids			
1. 126 D_2 A x H 206	35.9	0.97	0.2	126 D_2A x H 138	4.98	1.11	0.05	23 D_2 A x H 66	118.6	0.78	22
2. HC 73-1 x H 138	35.9	0.99	0.3	126 D_2A x H 92-2	4.94	1.01	0.10	5071 A x M 64 P_2	114.4	1.24	28
3. HC 73-1 x H 206	35.1	6.36	5.6*	126 D_2A x H 232	4.70	1.29	0.01	23 D_2A x H 49	109.8	1.09**	–60
4. 126 D_2 A x H 284	34.4	–0.49	16.8**	126 D_2A x C 6	4.87	1.04	0.03	23 D_2A x H 112	109.2	1.20	–35
5. HC 73-1 x H 284	33.5	–2.8	3.4	126 D_2A x H 47-1	4.60	0.71	0.03	5054 A x H 47-1	108.4	0.56	210*
6. 126 D_2 A x H 482	33.5	–1.39	3.5	126 D_2A x H 49	4.59	1.17	0.01	5094 A x H 49	105.7	0.80	52
7. 126 D_2 A x H 138	33.4	–2.51	–1.5	126 D_2A x M_{64} P_2	4.54	0.61	0.14	5094 A x H 206	102.8	0.58	10
8. HC-73-1 x H 47-1	33.4	–4.24	0.7	126 D_2A x H130-2	4.53	0.61	0.05	5094 A x M_{64} P_2	100.9	2.35*	–29
9. HC 73-1 x H 482	33.2	–3.49	–0.5	126 D_2A x H 206	4.52	0.49*	–0.05	5094 A x H 190-2	100.5	1.79	996**
10. 126 D_2 A x H 153	33.0	4.26	0.3	126 D_2A x H 482	4.47	0.64	0.18	5071 A x H 49	100.3	–0.19	51

*Significant at the 5 per cent level. **Significant at the 1 per cent level.

provided by 23 D_2 A for plant height, seed weight and ear weight; 5071 A for ear length and days to earing and 5054 A for ear bearing tillers. For non-linear response ($\bar{S}^2d$ non-significant) 5054 A provided maximum numbers of stable hybrids for ear length and days to earing, 5094 A for ear bearing tiller, HC 73-1 for seed weight, 126 D_2 A for plant height and 23 D_2 A for ear weight. This indicated that the differential genes for these attributes were distributed among various parents which could be combined into hybrid combination by using them as restorer (R) and/or maintainer (B) lines as the case may be.

Any generalization regarding stability of an individual genotype for all the characters was too difficult. The parents and hybrids did not exhibit uniform stability and linear response for all the characters studied (Table 3). Mean performance, b and $\bar{S}^2d$ attributes appeared to be specific for individual character for a given genotype. This may be explained on the basis of compromise and compensations among the developmental patterns of different characters. Bradshaw (1965) explained that maximum fitness can be obtained by adjustment in the plastic component traits. And expression of the component traits may shift in compensating manner in the changing environment in order to perform well for final trait, otherwise would result high unpredictable *g x e* interaction. Bains and Gupta (1972) observed that highly buffered populations for yield were poor to average in buffering ability for the component traits, whereas reverse was true for low buffering population in wheat.

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