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Combining Ability and Genotype x Environment Interaction for Dry Fodder Yield in Pearl Millet (*Pennisetum typhoides* (B.) S. & H.)

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ABSTRACT

The present investigation was undertaken with a view to work out combining ability and genotype×environment interaction for fodder yield in some newly developed inbreds and male sterile lines and its hybrids of pearl millet. Both additive and non-additive gene effects were found to be important. However, latter had a slight edge over former. Individual components of genetic variance showed interaction with environment. However, additive component was more stable. The heritability estimates were moderately high. Parents H 49, H 138 and 126 D_2A were the best general combiners. High specific combining ability effects in hybrids were reflected due to additive and epistatic gene interaction. *Gca* **effect and** *per se* **performance of the parents were independent which suggested the importance of working out** *gca* **effects. Best hybrid combinations based on** *per se* **performance,** *sca* **effect and stability parameters were 23 D_2A×H 46, 126 D_2A×M 64P_2 and HC 73-1×H 49. Joint regression analysis for stability parameters showed both linear and non-linear component of genotype× environment interaction to be significant. However, the former was more important.**

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INTRODUCTION

Pearl millet (*Pennisetum typhoides* (Burm.) S. &. H.) occupies major place in semi-arid and arid areas of the world. It is used not only for its grain but for dry fodder also. Therefore, an attempt to increase and stabilize dry fodder production alongwith grain yield shall go a long way in strengthening the economy of agriculture and animal husbandry of the pearl millet growing tracts. Considerable progress has been made in the recent past for the improvement of grain and green fodder yield of this crop. However, extremely meagre information is available in respect of dry fodder yield. Systematic and intensive efforts need to be made to improve dry fodder alongwith grain yield in this crop. The present investigation was, therefore, undertaken to study the combining ability and genotype × environment interaction for dry fodder yield in pearl millet.

MATERIAL AND METHODS

The material comprising of six females viz., five male sterile lines 5071A, 5054A,

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5094A, $23D_2A$, $126D_2A$ and an open pollinated local variety HC 73-1; 16 male parents and their 96 F_1 crosses alongwith 3 checks (PHB-14, NHB-5 and NHB-3), were grown in a simple lattice design in three environments, two at Hissar with 4 and 2 replications, respectively and one at Kodinar in Gujarat with 4 replications. Of the two environments, E_1 and E_2 at Hissar, the latter was represented by delayed sowing closer spacing and medium fertility level. On the other hand, E_1 was a normal environment with high fertility level. Each entry was represented by a single row plot of 3 m length, spaced at 60 × 20 cm. After sun drying five random plants were weighed and averaged to work out per plant dry matter yield (g).

Line × tester analysis was employed following Kempthorne (1957) and genotype×environment interaction was worked out following Eberhart and Russell (1966). For estimating the general and specific combining ability effects and their interactions with seasons the linear model given by Beil and Atkins (1967) was used.

RESULTS AND DISCUSSION

The analysis of variance for combining ability indicated significant mean squares due to females, males and females × males in all the environments when tested against error (Table 1). Moreover, mean squares due to females and males were even significant when tested against females × males mean square (Sij). Under the pooled analysis these were also significant even when tested against their respective interaction with environment. Only males × environment interaction (Gjj × E) was non-significant against females × males × environment (Sij×E). This indicated that the genetic causes appeared to be largely responsible for observed differences in females and males over hybrid combinations and also for pronounced interactions of females and females × males with environments.

A perusal of the unbiased estimates of the variance components showed consistent higher magnitude of males (Gjj) variance component as compared to the females (Gii) over all environments as also on pooled basis. The specific combining ability variance (σ^2_{sca}) was higher in magnitude than general combining ability variance (σ^2_{gca}) under each environment, consequently which yielded $\sigma^2_{sca} / \sigma^2_{gca}$ ratio > 1. Thus the predominant role of non-additive gene effects in the inheritance of this character was emerged from the present investigation. This was in conformity with the results obtained by Burton (1959), Gupta and Sidhu (1970) and Ramanujam and Verma (1976). Moderate to high narrow sense heritability (33.70, 34.03 and 44.42 per cent) was observed in various environments which further substantiated the importance of both non-additive and additive gene effects for dry fodder yield in this material. Similar findings were also reported for fodder yield in pearl millet by Pokhriyal *et al.* (1967).

Both the components of variance interacted with the environments. However, non-additive variance was more sensitive to environmental changes. Ramanujam and Verma (1976) reported the significant interactions of both the components with locations for fodder yield in pearl millet. The magnitude as well as greater stability of additive gene action together with reasonably high

TABLE 1

Analysis of combining ability variance under different environments and on pooled basis.

Variation due to		*d.f.*	*Mean squares*			
			E_1	E_2	E_3	*Pooled*
Combining ability analysis						
Females	(Gii)	5	55952*	21204*+	10954*+	10977*+
Males	(Gjj)	15	33353*+	13202*+	15058*+	6268*+
Females X Males	(Sij)	75	6774*	2577*	1327*	2521*+
Environments	(E)	2				325803*+
Gii X E		10				3419*
Gjj X E		30				1458*
Sij X E		750				1612*
Error		285	1934	1216	235	383
Variance components						
Females	(Gii)		768.5	582.1	150.4	238.5
Males	(Gjj)		1107.5	885.4	572.1	266.7
Females X Males	(Sij)		1209.9	680.9	273.2	303.0
Gii X E						112.9
Gjj X E						-25.7
Sij X E						1229.2
σ^2_{sca}			1209.9	680.9	273.2	303.0
σ^2_{gca}			860.9	664.8	265.3	246.7
σ^2_e			483.6	608.1	58.8	383.5
$\sigma^2_{sca} / \sigma^2_{gca}$			1.4	1.0	1.0	1.2
Heritability			33.7	34.0	44.4	26.4

*Significant at p=0.05 against error.

+Significant at p=0.05 against respective interaction.

Note: The error d.f. in respect of E_2 is 95.

heritability values further suggested its exploitation in the material.

To identify superior and prospective genotype which would be utilised as parent in further breeding programme, the combining ability effects are useful to pick-out such genotype. A perusal of the general combining ability (*gca*) effects on pooled basis 126 D_2A among the females and H 49 and H 138 among the males were found to be good general combiners (Table 2). On the contrary 5094A among the females and H 66 among the males were the poorest general combiners.

TABLE 2

Combining ability effects and stability parameters over 3 environments.

Genotype	*Combining ability effect*	*Mean Xi*	*bi*	S^{-2}_{di}
1	2	3	4	5
Females	**gca effect**			
1 5071A	- 7.85	98.7	0.28	- 137
2 5054A	- 10.43	162.4	1.23*	- 412
3 5094A	- 16.73*	137.5	1.03	520
4 HC 73-1	1.30	150.5	1.56	846
5 $23D_2A$	8.99	84.1	0.03	144
6 $126D_2A$	24.73*	115.1	0.55	- 180
SE (±)	4.47			
Males				
1 H 46	19.87	163.1	0.95	4443*
2 H 92-2	- 3.01	110.3	0.39	- 307
3 H 112	- 7.18	95.3	0.46	235
4 H 130-2	- 14.76	125.8	1.52	995
5 H 47-1	- 1.36	161.3	1.96*	- 59
6 H 153	- 18.88	119.1	1.08*	- 390
7 H 206	- 15.68	141.9	1.64*	- 28
8 H 284	- 14.65	128.1	0.95	653
9 H 49	37.93*	166.2	1.68	210
10 H 66	- 35.44*	124.0	1.16*	- 279
11 H 138	29.06	115.7	0.95*	- 413
12 H 482	9.24	106.2	0.43	427
13 M 64P2	9.68	169.2	1.65*	- 241
14 H 192-2	3.30	136.9	1.26	- 21
15 C-6	0.51	147.2	0.66	- 43
16 H 232	0.40	125.3	0.86	- 147
SE (±)	7.74			
Hybrids	**sca effect**			
1 x 1	- 27.23	157.6	1.30*	- 378
1 x 2	14.66	176.6	1.71*	- 385
1 x 3	- 13.76	144.0	1.28	6043*
1 x 4	32.66	182.8	0.03	128
1 x 5	7.17	170.8	0.70	527
1 x 6	6.35	152.4	0.60	2701*
1 x 7	32.32	181.6	0.53	1344*
1 x 8	18.62	168.9	1.57*	- 390
1 x 9	17.88	220.8	1.49*	- 311
1 x 10	- 59.16*	85.3	0.17	207

1	2	3	4	5
1 x 11	12.67	206.7	0.53	11456*
1 x 12	- 17.01	157.2	0.97	8673*
1 x 13	0.04	174.7	0.87	184
1 x 14	- 16.49	151.8	0.25	47
1 x 15	- 8.70	156.8	0.94*	- 369
1 x 16	- 0.01	166.3	1.50*	- 262
2 x 1	- 26.98	155.3	0.05	66
2 x 2	- 33.51	125.8	0.05	408
2 x 3	- 9.93	145.3	0.86	730
2 x 4	24.15	171.8	1.56*	- 25
2 x 5	52.83*	213.8	1.35*	- 355
2 x 6	5.35	148.8	0.93	3817*
2 x 7	- 17.05	129.6	0.32*	- 392
2 x 8	- 22.16	125.6	0.36	883
2 x 9	- 0.50	199.8	1.52	242
2 x 10	9.96	136.9	0.58	2604*
2 x 11	13.88	205.3	0.21	178
2 x 12	14.70	156.3	1.21	181
2 x 13	- 19.91	152.1	1.05*	- 342
2 x 14	14.33	180.0	1.12	1240*
2 x 15	- 7.41	155.5	1.03*	- 311
2 x 16	2.29	166.1	0.84*	- 356
3 x 1	14.88	190.8	0.76	1766*
3 x 2	- 6.96	146.1	0.96*	- 288
3 x 3	- 6.96	141.9	0.65*	- 311
3 x 4	- 38.55	102.8	0.33*	- 390
3 x 5	- 4.04	150.7	0.82*	- 254
3 x 6	11.56	148.8	0.72	392
3 x 7	38.28	178.7	1.15	856
3 x 8	- 14.00	127.4	0.89*	- 347
3 x 9	- 25.99	168.0	0.83	80
3 x 10	11.88	132.5	0.83	2515*
3 x 11	- 9.87	175.3	1.04	1715*
3 x 12	- 11.88	153.4	0.87*	- 390
3 x 13	13.26	179.0	0.29	299
3 x 14	9.56	168.9	1.17	1016
3 x 15	2.02	158.6	0.99	130
3 x 16	16.88	174.4	1.21*	- 362
4 x 1	6.97	200.9	0.03	8321*
4 x 2	40.60	211.6	1.87*	- 69
4 x 3	- 1.40	165.5	0.78	3687*
4 x 4	6.85	166.2	1.01	146
4 x 5	- 29.80	142.9	1.02	1514*
4 x 6	- 67.04*	88.2	0.61	919

1	2	3	4	5
4 x 7	- 35.57	122.9	0.67*	- 327
4 x 8	23.19	182.6	1.01	2770*
4 x 9	34.36	246.4	2.30*	- 175
4 x 10	- 7.84	130.8	0.89	1022
4 x 11	27.82	231.0	2.40	31937*
4 x 12	49.64*	233.0	1.52*	- 378
4 x 13	- 36.39	147.4	0.97	90
4 x 14	- 31.34	146.1	0.12	375
4 x 15	35.62	210.2	1.19*	- 282
4 x 16	- 15.69	159.2	0.39	36
5 x 1	66.23*	267.9	1.29*	- 371
5 x 2	- 1.72	177.1	1.56*	- 144
5 x 3	48.86*	223.4	1.67	715
5 x 4	- 54.30*	112.7	0.26	19
5 x 5	- 27.70	152.7	1.06	5095*
5 x 6	33.73	196.6	1.49	587
5 x 7	4.95	171.1	0.57	3846*
5 x 8	0.58	167.7	1.21	3632*
5 x 9	1.59	221.3	0.99	1199*
5 x 10	35.46	181.8	0.73	194
5 x 11	- 37.87	173.0	0.83*	- 382
5 x 12	- 56.55*	134.5	1.38	1648*
5 x 13	0.50	192.0	1.50	628
5 x 14	19.10	204.2	1.77	1544*
5 x 15	- 26.28	156.0	0.87*	- 390
5 x 16	- 6.58	176.6	1.29*	- 337
6 x 1	- 33.86	183.5	1.28*	- 364
6 x 2	- 13.06	181.4	1.46	1116*
6 x 3	- 16.81	173.5	1.23*	- 124
6 x 4	29.19	211.9	1.17*	- 350
6 x 5	1.54	197.7	1.54*	- 114
6 x 6	10.05	188.7	1.01	1706*
6 x 7	- 22.89	158.9	0.82*	374
6 x 8	- 6.29	176.6	1.20	- 170
6 x 9	- 27.34	208.1	0.90	1812*
6 x 10	9.70	171.8	0.73*	- 352
6 x 11	- 6.63	219.9	0.85	1423*
6 x 12	21.11	227.9	1.60*	- 293
6 x 13	42.49	249.7	1.97	2694*
6 x 14	4.87	205.7	1.85*	22
6 x 15	4.75	202.8	1.70*	-359
6 x 16	3.11	202.0	1.83	1153*
NHB-3	—	157.1	0.55*	- 383

1	2	3	4	5
NHB-5	—	130.5	0.58	3375*
PHB-14	—	196.5	0.69	272
SE (±)	17.31	18.81	—	—

*Significant at p = 0.05.

On an examination of the specific combining ability (*sca*) effects (Table 2) it is revealed that eight crosses displayed significant *sca* effects of which four hybrids were in desirable direction.

It was interesting to study the *sca* effect of different crosses in relation to the *gca* effects of both the parents involved. Four hybrids 5054 A × H 47-1 (2 × 5),HC 73-1×H 482 (4×12), 23 D_2A×H 46 (5×1) and 23 D_2A×H 112 (5×3) were desirable for specific combination as they exhibited positive and significant *sca* effects. These crosses involved only average×average parental combination in relation to their *gca* effects, showing thereby that in addition to additive gene action, epistatic interaction was also involved in expression of this character. These findings are not in agreement with that of Gupta and Sidhu (1970), Gupta and Gupta (1971), Gupta and Singh (1973) who reported high specific combining ability of a cross which had atleast one of the parent as good combiner.

It was interesting to note here the independence of *gca* effects and *per se* performance of parents (r=0.157) suggested the importance of working out *gca* effects for the selection of the parent for this trait. Paroda and Joshi (1970) in wheat and Solanki *et al.* (1974) in oats also came to similar conclusions. This indicated that the information on general combining ability effect alone may not be sufficient to predict the extent of *sca* effect in a particular cross combination in this crop for this trait. Therefore, information on general combining ability effect of the parent need to be supplemented by that of specific combining ability effect and its hybrid performance.

The joint regression analysis for stability showed significant difference among genotypes, environment (linear) as well as both components of genotypes × environment interaction, viz., genotype × environment (linear) and pooled deviations for parents and hybrids both (Table 3). The magnitude of predictable portion of G×E interactions was higher in both the cases particularly more pronounced in parents.

TABLE 3

Analysis of variance of stability parameters for hybrids and parents.

Variation due to	*d.f.*		*Mean square*	
	Hybrids	*Parents*	*Hybrids*	*Parents*
Genotypes	98	21	3528.1*	1824.2*
Environments (linear)	1	1	675941.7*	98622.5*
Genotype X Environments (linear)	98	21	1809.5*	1351.9*
Pooled deviation	99	22	1597.9*	659.3*
Pooled error	686	147	392.3	413.5

*Significant at p = 0.05

An examination of Table 2 revealed an absence of G×E interaction for 5 females, 9 males and 32 F_1s hybrids (both bi and $\bar{S}^2_{di}$ non significant). As many as 1 female, 6 males and 39 hybrids indicated G×E interactions of the predidictable type (only bi significant). While only one male and 28 F_1's hybrids exhibited presence of only non-linear portion of G×E interaction (only $\bar{S}^2_{di}$ significant) and hence, it would make their performance under environmental changes unpredictable. These results are broadly in agreement with a number of earlier studies in a wide range of crop plants (Hooda *et al.* 1978 ; Singh and Gupta, 1978 in pearl millet ; Russell and Eberhart, 1968 in Corn ; Joppa *et al.*, 1971 in wheat ; Paroda and Hayes, 1971 in barley). The individual analysis thus conformed to the information obtained from analysis of variance for stability parameters (Table 3) where both the components of G × E interactions, i. e. linear as well as non-linear were found to be important.

It was not clear from the data whether bi values of the parents were transmitted to their crosses nor could it be made out if there was any apparent association between three parameters of stability.

A number of specific cross combinations gave encouraging performance considering *per se* performance, *sca* effects and stability parameters. Specifically three hybrids, viz., $23D_2A$×H 46, $126D_2A$ × $M64P_2$ and HC 73 – 1 × H 49, which significantly out yielded over the best check PHB-14. These hybrids could be screened out as promising hybrids for this trait in commercial exploitation of heterosis.

The results of the present investigation alongwith the information available in literature reveals the predominant role of both non-additive and additive genetic variance for dry fodder yield in this crop with the former having a slight edge over the latter. Under this situation the development of high yielding F_1's appears to be desirable approach. Also some variation of reciprocal recurrent selection which utilizes both types of gene effects could be beneficially utilized. Greater stability of the additive component together with moderate heritable estimates suggested its economic utility for exploitation in this material. For this purpose, parents H49, H 138, H 46 and $126D_2B$ showing high *gca* effects could be exploited.

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