Int.J.Curr.Microbiol.App.Sci (2020) *9*(1): 698-706

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 9 Number 1 (2020)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2020.901.075

Combining Ability and Gene Action for Grain Yield and Related Components in Pearl Millet [*Pennisetum glaucum* (L.) R.Br.]

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Keywords

Combining ability, Gene action, Pearl millet, Line × tester analysis, Crosses, Yield

Article Info

Accepted:
15 December 2019
Available Online:
20 January 2020

A B S T R A C T

This investigation was carried out to study combining ability along with inheritance of grain yield and its component traits in 100 hybrids of pearl millet which were generated through line x tester mating design using 5 male sterile lines and 20 restorers as parental material at ICRISAT, Hyderabad during *Summer*, 2018. These hybrids were evaluated in randomized block design with 3 replications in 3 environments during *Kharif*, 2018 at Rajasthan Agricultural Research Institute, Durgapura (Jaipur). In results, the ratio of variance due to GCA and SCA indicated that predominance of non-additive gene action for all the characters studied except ear girth. GCA effects revealed that parents like ICMA 04999 and ICMA-843-22 (female), RIB-192, RIB-15270, RIB-494 and MIR-525-2 (male) were good general combiners for grain yield and some contributing characters. On the basis of SCA effects the crosses namely ICMA-843-22 x RIB-3135-18, ICMA-04999 x J-2290, ICMA-93333 x RIB-15270 were identified as superior for grain yield and related traits over the

Introduction

Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is the most drought tolerant among the cultivated food grain crops. It is widely distributed across the arid and semi arid areas. Pearl millet is the fourth most important food crop after rice, wheat and sorghum. It occupies an area of 7.4 million ha in the country and Rajasthan having the biggest share 41.54 lakh ha. Its production in the country is 9.13 million tonnes and in Rajasthan it is 32.86 lakh tonnes in 2018 (Directorate of millet development). The combining ability provides better parents and desirable crosses to be used in formulation of systematic breeding and provides the nature of gene action involved in the inheritance of various characters. In a breeding programme, Selection of suitable parents is the most required for the success of the program. Some parents produce outstanding progenies on crossing while others, apparently equally desirable, turn out to be good combiners. This necessitates the evaluation of the parental material (inbreds) for their combining ability. The lines giving superior performance in SCA are said to be having high specific combining ability (SCA) and are best utilized in hybrid production programme.

Materials and Methods

The experimental material for present study consisted of 5 male sterile lines (ICMA-93333, ICMA-843-22, ICMA-97111, ICMA-04999, ICMA-94111 from The International Crops Research Institute for the Semi-Arid Tropics, Hyderabad) and 20 testers (RIB-192, RIB-494, RIB-3135-18, RIB-135071, MIR-525-2, RIB-155076, RIB-155137, RIB-155147, RIB-15153, RIB-15159, RIB-15181, RIB-15185, RIB-15197, RIB-15217, RIB-15243, RIB-15259, RIB-15270 From RARI, Durgapura, Jaipur; J-2290, J-2340 from Junagadh Gujarat and H-77/833-2 from CCS Haryana Agriculture University). The 100 crosses were generated using line x tester mating design at International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad during summer, 2018. These hybrids were grown in randomized block design with three replications in three environments created by differentiating date of sowing (the environment E1, E2 and E3 were created by early sowing, normal sowing and late sowing respectively) at Rajasthan Agricultural Research Institute (RARI), Durgapura (Jaipur) during Kharif, 2018. Each plot consisted of two rows each of 5 meter length with row spacing of 50 cm and plant to plant spacing of 15 cm. All recommended cultural practices were followed to raise good crop. The observations were recorded on twelve morphological characters namely days to 50% flowering, days to maturity, plant height (cm), number of effective tillers per plant, ear length (cm),ear girth (cm), flag leaf area (cm^2), dry fodder yield per plant(g), grain yield per plant (g), grain density (cm^2), 1000-grain weight (g), and harvest index (%). The mean data were subjected to analyze combining ability as per the method suggested by Kempthorne (1957).

Results and Discussion

Combining ability variances

Combining ability analysis gives an idea about the magnitude of various types of gene action involved in the expression of quantitative traits for formulating an efficient breeding programme and for obtaining maximum possible gain in selection. In the present study, combining ability indicated that mean sum of squares due to crosses were significant for all the traits in all the environments (Table 1). Partitioning of these mean sum of squares due to lines were significant for all the characters except plant height, number of effective tillers and ear girth. While testers were found to be significant for most of the traits except harvest index and mean sum of squares due to interaction of males x females were also significant for most of the traits except plant height. Significant variance due to GCA x E for the characters indicated its sensitivity to environments. Similarly, the sensitivity of SCA to environments was observed for the traits. The ratio of variance GCA / SCA is found less than unity for all the traits except ear girth (Table 2) thereby indicating the preponderance of non-additive gene actions in the expression of the corresponding traits. SCA effects highly significant for various traits indicated epistatic gene action predominant for the characters.

Table.1 ANOVA for combining ability for grain yield per plant and its component traits based on data

		Mean Squares											
Source of variation	**d.f.**	**Days to 50% flowering**	**Days to maturity**	**Plant height (cm)**	**No. of effective tillers/plant**	**Penicle length (cm)**	**Penicle girth (cm)**	**Flag leaf area (cm^2)**	**Dry fodder yield /plant (g)**	**Grain yield /plant (g)**	**Grain density/cm^2**	**Test weight (g)**	**Harvest index %**
Replication (r)	2	**2.543**	**0.84**	**65.02**	**0.015**	**10.15**	**0.035**	**26.135**	**19.932**	**6.06**	**10.381**	**2.053**	**2.872**
Environments (e)	2	**6984.663****	**5864.20****	**136066.621****	**1.175****	**576.128****	**24.259****	**65096.465****	**75465.466****	**11439.732****	**1944.987****	**824.073****	**14715.708****
Rep. x Env.	4	**1.831**	**2.403**	**100.296**	**0.095**	**3.002**	**0.028**	**32.968**	**38.294**	**16.963***	**12.164**	**0.743**	**30.533**
Crosses	99	**13.681****	**11.331****	**394.722****	**0.627****	**19.826****	**0.087****	**1158.815****	**493.348****	**44.955****	**78.142****	**5.115****	**182.538****
line (l)	4	**38.748****	**34.257****	**468.919**	**0.143**	**19.051**	**0.341****	**363.398**	**4096.089****	**219.431****	**163.213***	**12.933****	**959.651****
tester (t)	19	**22.84****	**19.837****	**914.377****	**1.025***	**62.657****	**0.243****	**2987.978****	**605.987****	**66.141****	**143.733****	**12.0824****	**76.179**
l x t	76	**10.071****	**7.998****	**260.903**	**0.553****	**9.159****	**0.034***	**743.388****	**275.571****	**30.475****	**57.267****	**2.962****	**168.227****
Environment x Crosses	198	**7.129****	**6.252****	**283.327****	**0.393****	**7.949****	**0.043****	**737.366****	**258.224****	**22.715****	**35.300****	**3.395****	**70.572****
Environment x Line effect	8	**41.096****	**36.179****	**477.300***	**0.197**	**19.449****	**0.154****	**1566.751****	**1420.838****	**51.161****	**103.919****	**6.868****	**135.715**
Environment x tester effect	38	**9.659****	**8.340****	**566.026****	**0.327**	**19.936****	**0.093****	**1326.133****	**319.108****	**39.975****	**85.833****	**9.873****	**57.495**
Environment x Line x tester effect	152	**4.708****	**4.155**	**202.443**	**0.420****	**4.348**	**0.025**	**546.522****	**181.813****	**16.903****	**19.056**	**1.592**	**70.412****
Error	594	**4.884**	**4.378**	**213.044**	**0.066**	**4.032**	**0.026**	**272.1134**	**27.701**	**6.634**	**17.2**	**1.706**	**21.505**
Total	899	**21.856**	**18.576**	**549.932**	**0.203**	**7.916**	**0.09**	**614.831**	**297.606**	**39.875**	**32.149**	**4.28**	**82.734**

Table.2 Estimates of combining ability variances for various traits over the environments

Source of variation	Days to 50% flowering	Days to maturity	Plant height	No. of effective tillers/plant	Ear length	Ear girth	Flag leaf area	Dry fodder yield /plant	Grain yield /plant	Grain density	1000-grain weight	Harvest index
$\sigma^2 GCA$	0.237	0.208	4.52	0.004	0.332	0.002	12.791	20.668	1.215	1.226	0.097	4.435
$\sigma^2 SCA$	0.668	0.486	8.73	0.051	0.628	0.001	56.300	27.746	2.712	4.643	0.162	16.586
$\sigma^2 GCA / \sigma^2 SCA$	0.35	0.43	0.52	0.08	0.53	2	0.23	0.74	0.45	0.26	0.6	0.27
$\sigma^2 A$	0.95	0.832	18.11	0.01	1.32	0.009	51.164	82.673	4.861	4.906	0.391	17.740
$\sigma^2 D$	2.67	1.94	34.94	0.20	2.51	0.004	225.203	110.984	10.850	18.573	0.651	66.344
$\sigma^2 A / \sigma^2 D$	0.36	0.43	0.52	0.08	0.52	2.10	0.227	0.744	0.448	0.264	0.601	0.267
Line (l)	11.44	12.21	4.79	0.92	3.88	15.79	1.26	33.54	19.72	8.43	10.21	21.24
Tester (t)	32.04	33.59	44.45	31.34	60.65	53.65	49.48	23.57	28.23	35.3	45.32	8
Line x Tester (lxt)	56.51	54.18	50.74	67.72	35.46	30.55	49.24	42.88	52.04	56.25	44.45	70.74

Table.3 Best performing parents (lines and testers) and crosses on the basis of GCA and SCA effects over the environments

Characters	Parents		Crosses
	Lines	Testers	
Days to 50% flowering	NS	RIB-155137, RIB-155076, J-2290	ICMA-843-22 x RIB-3135-18 ICMA-843-22 x RIB-155137 ICMA-97111 x RIB-3135-18
Days to maturity	ICMA-93333	RIB-192, RIB-135076, RIB-155137, J-2290	ICMA-94111 x RIB-3135-18
Plant height	ICMA-04999	RIB-494, RIB-15153, J-2340	ICMA-843-22 x RIB-192 ICMA-94111 x RIB-15197
Number of effective tillers	NS	RIB-15259, RIB-15217, H-77/833-2, RIB-494	NS
Ear length	ICMA-04999	RIB-494, RIB-192, J-2340, RIB-135071, RIB-155137	ICMA-04999 x RIB-192 NS
Ear girth	ICMA-93333, ICMA-843-22	H-77/833-2, RIB-155076, MIR-525-2, J-2340, RIB-135071	ICMA-93333 x RIB-15185 ICMA-843-22 x RIB-15185
Flag leaf area	ICMA-843-22	J-2290, RIB-15185, RIB-15259, J-2340, H-77/833-2, RIB-15217, RIB-155076	NS
Dry fodder yield per plant	ICMA-04999	RIB-494, RIB-192, RIB-15270, RIB-3135-18, MIR-525-2, RIB-15197, RIB-15153	ICMA-843-22 x RIB-192 ICMA-843-22 x RIB-3135-18 ICMA-94111 x RIB-494
Grain yield	ICMA-04999, ICMA-843-22	RIB-192, RIB-15270, RIB-15197, RIB-494, MIR-525-2	ICMA-843-22 x RIB-3135-18 ICMA-93333 x RIB-15270 ICMA-93333 x RIB-15259
Grain density	ICMA-97111	RIB-15259, H-77/833-2, RIB-135071, RIB-155137, RIB-15191	NS
1000- grain weight	ICMA-843-22	MIR-525-2, H-77/833-2, RIB-3135-18, RIB-155076, RIB-15243	ICMA-97111 x RIB-494 ICMA-97111 x RIB-494 ICMA-94111 x RIB-15185
Harvest index	ICMA-843-22, ICMA-94111, ICMA-04999	RIB-155137, RIB-15197, RIB-15243, RIB-155076	ICMA-94111xRIB-15217 ICMA-04999 xJ-2340 ICMA-04999 x J-2290

Table.4 Specific combining ability effects of best crosses for grain yield per plant and other attributes in pearl millet.

Crosses	Grain yield	Days to 50% flowering	Days to maturity	Plant height	Number of Effective tillers	Ear length	Ear girth	Flag leaf area	Dry fodder yield per plant	Grain density	1000-Grain weight	Harvest index
ICMA-843-22 x RIB-1335-18	3.943**	-1.216	-0.481	-6.280	0.209*	0.392	-0.069	3.515	6.177**	-2.911*	0.107	2.599
ICMA- 93333 x RIB-15270	3.055**	1.873**	1.519*	1.931	0.187	0.942	-0.052	0.469	3.759*	0.111	0.332	0.984
ICMA-94111 x RIB-1335-18	0.223	-1.477*	-1.387*	5.470	0.107	-0.443	0.018	-9.122	1.213	-0.778	-0.153	0.622
ICMA-94111 x RIB-15159	3.056*	-0.477	-0.120	-0.152	-0.001	-0.139	-0.072	1.674	10.834	-2.622	0.098	-2.368
ICMA-94111 x H-77/833-2	2.034*	0.190	0.102	-2.779	-0.207*	-2.086**	0.065	-14.590**	-5.948**	0.244	-0.344	5.629**
ICMA-93333 x RIB-15259	2.920**	1.060	-0.814	1.176	0.058	0.073	-0.043	7.829	3.806*	-2.911	0.178	1.049
ICMA-94111 x RIB-15197	1.904*	-0.232	-0.142	4.435	0.282**	0.528	0.042	13.912**	-6.546**	-1.933	0.449	4.704**
ICMA-93333 x J-2340	1.5I7	-1.038	-0.570	5.443	-0.137	-0.023	-0.004	-4.515	1.484	0.756	-0.035	-1.374
ICMA-843-22 x RIB-192	2.276**	1.407*	1.097	1.931	0.009	-0.563	0.034	3.450	10.654**	7.178**	-0.155	-2.339
ICMA-94111 x RIB-135071	2.382**	-0.543	-0.320	8.439	-0.085	-0.186	0.063	12.592	1.889	-2.178	0.698	0.573

The present findings supported by the reports of Bhardwaj *et al.,* (2015) Mungra *et al.,* (2015) Pawar *et al.,* (2015) Athoni *et al.,* (2016) Karvar *et al.,* (2017) Badurkar *et al.,* (2018); Gavali *et al.,* (*2018*); Kumawat *et al.,* (2019) who reported preponderance of non-additive genetic effects. On the other hand, predominance of GCA variance or additive gene action reported by Chotaliya *et al.,* (2010; Jethva *et al.,* (2011) Mungra *et al.,* (2015) Pawar *et al.,* (2015); Krishnan *et al.,* (2017) Gavali *et al.,* (2018) for 1000-grain weight which are in opposition to findings of the present investigation. Such differences are expected due to differences in the experimental material and the experiments of evaluation. It is thus evident grain yield and other yield components controlled by both additive and non-additive gene effects as revealed by the combining ability analysis. However, SCA variance was more pronounced than GCA variance for all the characters except ear girth. It is therefore, suggested that the material used in the present study may be effectively utilized in the hybrid development.

The proportional contribution of lines, testers and their interaction to total variance(%) over the environments showed maximum contribution of lines to total variance for dry fodder yield per plant (33.54%) followed by harvest index (21.24%). The maximum contribution of tester to total variance was for ear length (60.65%) followed by ear girth (53.65%). The maximum contribution to total variance in Line x tester interaction was displayed by harvest index (70.74%) followed by number of effective tillers per plant (67.72%) over the environments. Similar results were also reported by Kumar *et al.,* (2017) and Badurkar *et al.,* (2018).

GCA and SCA effects

The GCA and SCA effects in this section are based on the data pooled over the three environments. The best performing parents (lines and testers) and cross combinations on the basis of GCA and SCA effects (Table 3) revealed that none of the parents was found good general combiner for all the characters which suggested breeding for these characters would be effective when material is tested over a wide range of environments. The female line ICMA-04999 was found to be desirable for plant height, ear length, dry fodder yield per plant and harvest index while ICMA-843-22 was found desirable for plant ear girth, flag leaf area, 1000- grain weight and harvest index. Among males, RIB-192, RIB-15270, RIB-15270, RIB-494 and MIR-525-2 exhibited significant GCA effects in over the environments for grain yield while RIB-192 exhibited significant and desirable GCA effects for ear length and dry fodder yield per plant. Male lines RIB-15270 exhibited significant and desirable GCA effects for number of effective tillers per plant and dry fodder yield per plant while RIB-15197 exhibited significant and desirable GCA effects for dry fodder yield, grain density and harvest index while RIB-494 exhibited significant and desirable GCA effects for plant height, no. of effective tillers, ear length and dry fodder yield and MIR-525-2 desirable for ear girth, dry fodder yield and test weight. It may be summarized that the parents ICMA-04999, ICMA-843-22 and RIB-192, RIB-15270, RIB-494, MIR-525-2 were better general combiners for grain yield per plant, dry fodder yield per plant over the environments reported earlier by *Athoni et al.,* (2016). *Krishnan et al.,* (2017) also reported various lines and testers, having good combining ability behavior for yield and its attributing characters in pearl millet. Top three crosses on the basis of high SCA effects for different characters are presented in Table 3.

In conclusion, the ratio of variance GCA / SCA were less then unity for all the characters except ear girth. This indicating the involvement non-additive gene effects in the inheritance of these characters. It may be summarized that the parents male parents RIB-192, RIB-15270, RIB-15270, RIB-494, MIR-525-2 were better general combiners and to be used as components of synthetics or composites of pearl millet. The promising crosses identified on the basis of SCA effects for seed yield per plant were ICMA-843-22 x RIB- 3135-18, ICMA-04999 x J-2290, ICMA-94111 x RIB-15159, ICMA-93333 x RIB- 15270, ICMA-93333 x RIB-15259, ICMA-97111 x RIB- 15181, ICMA-97111 x RIIB-135071, ICMA-94111 x 15185, ICMA-94111 x RIB- 135071 and ICMA- 843-22 x RIB-192.

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How to cite this article:

Anita Pareek, R.V. Singh, L.D. Sharma and Shravan K. Sharma. 2020. Combining Ability and Gene Action for Grain Yield and Related Components in Pearl Millet [*Pennisetum glaucum* (L.) R.Br.]. *Int.J.Curr.Microbiol.App.Sci*. 9(01): 698-706.
doi: https://doi.org/10.20546/ijcmas.2020.901.075