Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2021; 10(1): 1882-1885
Received: 24-11-2020
Accepted: 26-12-2020

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Combining ability studies in pearl millet [*Pennisetum glaucum* (L.) R. Br.]

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Abstract
The experiment was conducted with 40 hybrids which were developed through line x tester mating design using four male sterile lines and ten newly developed in breads as male parents, their forty crosses and two standard hybrid check Aadishakti and Mahashakti. The parents, hybrids and two standard checks were evaluated during KHARIF, 2019 season for nine characters. Significant differences were observed for all the nine characters studied. Among the females, DHLB-27A was found best general combiner for grain yield and had significant GCA effects for five other characters. None of the female parent were good combiner for earliness. Among male parents, S-19/18, S-19/20 and S-19/23 were found to be good general combiner for most of the characters under study. The cross DHLB-27A x S-19/18 was the best specific combiner for grain yield per plant followed by DHLB-27A x S-19/20 and DHLB 27A x S-19/23. They produced significant and desirable SCA effects for most of the traits studied, including potential for exploiting hybrid vigour in breeding programme.

Keywords: Pearl millet, GCA, SCA, gene action, grain yield

Introduction
Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is a highly cross pollinated crop with protogynous flowering and wind borne pollination mechanism, which fulfils one of the essential biological requirements for hybrid development. In it occupies an area of 6.93 million ha with an average production of 8.61 million tones and productivity of 1243 kg/ha (Directorate of Millets Development, 2020; Project Coordinator Review, 2020) [5]. Combining ability provides useful information regarding the selection of suitable parents for effective hybridization programme and at the same time elucidates the nature and magnitude of gene action varies with genetic architecture of population involve in hybridization therefore, it is necessary to evaluate the parents for their combining ability. This information enables the breeder to their utility in development of high yielding F_1 hybrids in pearl millet, where hybrids are being cultivated on commercial SCAle. Keeping the above fact in mind, the present investigation was conducted to assess the combining ability for yield and its contributing traits. To determine the nature and magnitude of gene action, line x tester mating design was utilized with a view to identify good combiners including CMS lines and restorers.

Materials and Methods
The present investigation was carried at Post Graduate Institute Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri during *Kharif*, 2019. The experimental material consisted four male sterile lines namely DHLB-21A, DHLB-23A, DHLB-24A and DHLB-27A and ten testers *viz.*, S-19/16, S-19/17, S-19/18, S-19/20, S-19/21, S-19/22, S-19/23, S-19/24, S-19/25 and S-19/27 were crossed in Line x Tester fashion during summer, 2019. A total 56 treatments comprising 4 male sterile lines (Female parents), 10 restorers (Male parents), 40 F_1s and 2 check hybrids *viz.*, Aadishakti and mahashakti were grown in a randomized block design with two replications. Each entry planted in 4.5 meter row with spacing of 50 x 15 cm and two row of each entry was planted in each replication. The observations were recorded on ten randomly selected competitive plants of each treatment from each replication for nine characters *viz.*, days to 50% flowering, days to maturity, plant height, and number of tilllers/plant, earhead length, earhead girth, 1000 grain weight, grain yield per plant and fodder yield per plant. The combining ability analysis was done as per Kempthorne (1957) [9] and modified by Arunachalam (1974) [1].

Result and Discussion

Analysis of variance for combining ability was done for nine characters and presented in Table1. Mean squares due to line x tester were significant for all characters. The mean due to lines were significant for the traits Earhead girth, grain yield/plant and fodder yield/plant. Variations due to testers were significant for all the traits under study. Significant differences were found among the parents for all the traits indicating that the materials selected were diverse and resulted in certain of substantial genetic variability in the crosses. Combining ability analysis (Table 2) revealed that GCA was highly significant for all the studied characters indicated that additive variance is predominant for these characters. These results were in conformity with Lakshmana *et al.*, (2003) [10], Dhuppe *et al.*, (2006) [4], Badurkar *et al.*, (2018) [2] and Kana *et al.*, (2003). While SCA varinces were highly significant for all the traits indicated epistatic gene action is predominant for the characters. Similar results were also reported by Yadav *et al.*, (2002) [14] and Patel *et al.*, (2008) [11]. The magnitude of specific combining ability variances (6^2SCA) was higher than general combining ability variances (6^2GCA), for characters days to 50 per cent flowering, plant height, earhead length, earhead girth, 1000 grain weight, fodder yield the SCA variance are higher than the GCA variance which indicates the preponderance of non-additive gene action to control these characters Dhuppe *et al.*, (2006) [4] Karvar *et al.*, (2017) [8] and Gavali *et al.*, (2018) [6] and therefore, heterosis breeding will be rewarding.

Estimates of GCA and SCA effects for nine characters are presented in Table 3 and Table 4, respectively. In the present investigation the parent, DHLB-27A showed significant positive GCA effect for grain yield per plant, No. of effective tillers per plant, 1000 grain weight, earhead length and also shows significant negative GCA for plant height. Therefore, DHLB-27A proved to be good general combiner for grain yield per plant, No. of effective tillers per plant, 1000 grain weight, earhead length and plant height. While, the parents DHLB-21A showed positive GCA effect for Earhead length, 1000 grain weight and fodder yield per plant, which prove their potential to be good parent for said characters. None of the female parent showed significant GCA for earliness.

The parent S-19/20 was showed significant positive GCA effects for number of effective tillers/plant, earhead length, earhead girth, 1000 grain weight, grain yield/plant, fodder yield/ plant and showed significant negative GCA effects for Plant height. The parent S-19/18 was showed significant positive GCA effects for Number of effective tillers/ plant, earhead length Earhead girth, 1000 grain weight, grain yield/ plant, fodder yield/plant. The parent S-19/23 was showed significant positive GCA effects for Number of effective tillers/ plant, earhead length, Earhead girth, 1000 grain weight, grain yield/ plant, fodder yield/plant. The parent S-19/25 was showed significant positive GCA effects for number of effective tillers/plant, earhead girth, grain yield/plant, fodder yield/ plant and showed negative GCA effects for Plant height. The parent S-19/27 was showed significant positive GCA effects for1000 grain weight and showed negative GCA effects for Days to 50% flowering, days to maturity, plant height. The parent S-19/16 were good general combiner for Days to 50% flowering, days to maturity, and 1000 grain weight, while the tester S-19/17 and S-19/21 were good general combiner for Days to 50% flowering, days to maturity, plant height.

From the studies on general combining ability effects it is apparent that the inclusion of DHLB-27A and DHLB-23A as female parent and S-19/18, S-19/20 and S-19/23, as male parents in crossing programme would provide greater opportunity to generate more number of desirable transgressed segregants for grain yield and its components, as these parents possessed high GCA effects for grain yield per plant along with one or more yield components in desirable direction.

Sprague and Tatum (1942) [13] reported that the SCA effect is due to non-additive genetic proportion. It is an important parameter for judging and selecting superior cross combinations, which might be exploited through heterosis breeding programme. The studies on specific combining ability effects it was observed that DHLB-27A x S-19/18 to be the best specific combination for grain yield per plant as well as number of tillers per plant, earhead length, 1000 grain weight, grain yield per plant and fodder yield per plant. However, DHLB-27A x S-19/20 for grain yield, number of tillers per plant, earhead length DHLB-27A x –S-19/23 also best specific combining ability for the number of tillers per plant and grain yield per plant similar result were in conforming with Rathore *et al.*,(2004) [12] and Bhandari *et al.*, (2007) [3].

Table 1: Combining ability analysis for different character in pearl millet

Sources of Variation	d.f	Days to 50% flowering	Days to maturity	Plant height(cm)	No. of Effective tillers/ plant	Earhead length (cm)	Earhead girth(cm)	1000 grain weight (g)	Grain yield /plant (g)	Fodder yield /plant (g)
Replications	1	0.05	1.80	31.74	0.01	0.01	0.09	0.06	1.33	82.11
Crosses	39	9.74**	19.07**	298.10**	0.16**	9.63**	1.86**	7.62**	198.84**	716.74**
Line effect	3	3.95	4.60	376.24	0.03	7.56	2.50*	8.40	218.98**	561.05
Tester effect	9	24.02**	68.64 **	611.52**	0.53**	29.86 **	4.72 **	20.82 **	678.18**	2070.53**
Line × Tester effect	27	5.61 **	4.16 **	184.94 **	0.04 **	3.11 **	0.83 **	3.13**	36.81 **	282.77**
Error	39	1.05	3.65	26.41	0.01	0.34	0.06	0.14	12.53	54.84

Table 2: The estimate of GCA, SCA, additive and dominance variances and gene action for different characters in pearl millet

Sr. No.	Variances	Days to 50% flowering	Days to maturity	Plant height (cm)	No.of effective tillers/ plant	Earhead length (cm)	Earhead girth (cm)	1000 grain weight (g)	Grain yield/ plant (g)	Fodder yield/ plant (g)
1	GCA	0.91**	8.18**	33.83**	0.02**	1.31**	0.25**	1.03**	31.25**	89.75**
2	SCA	2.24**	2.39**	82.34**	0.01**	1.39**	0.39**	1.49**	12.92**	111.79**
3.	σ^2A	1.84	0.51	67.66	0.04	2.63	0.51	2.07	62.52	179.52
4.	σ^2D	2.24	2.39	82.34	0.01	1.39	0.39	1.49	12.92	111.79
5.	σ^2A: σ^2D	0.82	0.21	0.82	2.10	1.88	1.30	1.38	4.84	1.61

*,** denote significant at 5% and 1% level respectively

Table 3: The estimate of general combining ability effect in different characters in pearl millet

Sr. No.	Parents	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of effective tillers/ plant	Earhead length (cm)	Earhead girth (cm)	1000 grain weight (g)	Grain yield/ plant (g)	Fodder yield/ plant (g)
1	DHLB-21A	-0.12	-0.25	-3.39**	0.01	0.45**	-0.26**	0.26**	1.37	4.77**
2	DHLB-23A	0.62**	0.05	-0.79	-0.05**	-0.36**	0.51**	0.01	0.14	3.03
3	DHLB-24A	-0.42	-0.45	6.30**	0.00	-0.67**	-0.21**	-0.89**	-4.61**	-7.20**
4	DHLB27A	-0.07	0.65	-2.12**	0.04**	0.58**	-0.03	0.62**	3.10**	-0.60
	SE	0.24	0.40	1.01	0.01	0.13	0.05	0.08	0.74	1.72
	CD at 5%	0.48	0.80	2.04	0.02	0.26	0.11	0.16	1.50	3.48
	CD at 1%	0.64	1.07	2.72	0.03	0.34	0.14	0.22	2.00	4.66
5	S-19/16	-1.37**	-1.95**	6.15**	-0.27**	-0.33	-0.45**	0.35**	-0.40	-14.92**
6	S-19/17	-2.25**	-3.70**	-3.62*	-0.28**	-3.80**	-0.39**	-1.55**	-14.72**	-16.57**
7	S-19/18	2.50*	4.30**	10.79**	0.35**	2.24**	0.96**	1.95**	10.91**	21.48**
8	S-19/20	1.50**	2.30*	-5.31**	0.22**	1.51**	0.59**	1.77**	7.72**	11.62**
9	S-19/21	-1.50**	-2.20**	-13.20**	-0.27**	0.53*	-1.31**	-2.15**	-10.50**	-17.19**
10	S-19/22	1.00*	-0.20	5.09**	-0.02	-0.63**	-0.58**	-1.74**	-2.79**	6.38*
11	S-19/23	1.75**	4.55**	5.24**	0.41**	2.63**	1.07**	2.15**	11.63**	18.73**
12	S-19/24	0.37	-0.20	11.20**	-0.04*	-0.28	0.14	-1.19**	0.80	4.32
13	S-19/25	0.25	0.30	-6.57**	0.06**	0.10	0.44**	-0.00	6.07*	7.78**
14	S-19/27	-2.25**	-3.20**	-9.77**	-0.15**	-1.98**	-0.47**	0.41**	-8.72**	-21.65**
	SE	0.37	0.63	1.59	0.02	0.20	0.08	0.13	1.17	2.72
	CD at 5%	0.76	1.27	3.22	0.04	0.41	0.17	0.26	2.37	5.50
	CD at 1%	1.01	1.70	4.31	0.05	0.54	0.23	0.35	6.34	7.36

*, ** denote significant at 5% and 1% level respectively

Table 4: The estimate of specific combining ability effect for different characters in pearl millet

Sr. No.	Parents	Days to 50% flowering	Days to maturity	Plant height (cm)	No.of effective tillers/ plant	Earhead length(cm)	Earhead girth (cm)	1000 grain weight (g)	Grain yield/ plant (g)	Fodder yield/ plant (g)
1	DHLB-21A ×S-19/16	0.62	1.25	2.83	0.17**	-0.49	-1.19**	-0.09	2.36	-3.71
2	× S-19/17	0.50	0.00	16.73**	0.14**	-0.93*	0.74**	1.53**	-2.24	25.13**
3	× S-19/18	2.50**	1.00	-6.89*	-0.04	-0.14	0.19	0.88**	-0.25	-7.91
4	× S-19/20	0.25	0.00	-7.83*	-0.14**	-0.12	0.00	0.20	2.85	-6.11
5	× S-19/21	-0.25	0.50	-0.35	0.03	1.09**	-0.08	0.69*	-0.74	-13.56*
6	× S-19/22	-1.75*	-0.50	-2.98	-0.19**	0.71	-0.55**	-2.10**	0.80	-7.57
7	× S-19/23	-1.50	0.75	-7.14*	-0.03	-1.22**	0.23	0.50	0.51	-0.80
8	× S-19/24	0.87	0.50	-17.39**	-0.01	-0.88*	-0.53**	-2.37**	-1.05	-12.01*
9	× S-19/25	2.50**	-3.00*	4.27	-0.00	-0.41	0.06	0.573*	0.82	7.96
10	× S-19/27	-0.50	-0.50	18.75**	0.08*	2.39**	1.13**	0.19	-3.05	18.6**
11	DHLB-23A × S-19/16	-2.62**	-1.05	-1.49	0.15**	0.56	0.38*	0.08	2.94	-0.31
12	× S-19/17	2.25**	0.70	-11.28**	-0.01	0.63	0.08	0.07	0.49	-8.98
13	× S-19/18	-1.95*	-1.30	-0.82	-0.15**	-0.21	-0.40*	-0.47	-1.94	-6.07
14	× S-19/20	0.50	-0.30	-2.47	-0.12**	0.02	-0.08	1.39**	-4.81*	-0.15
15	× S-19/21	1.00	1.20	8.49*	0.02	-0.17	0.91**	-0.34	0.24	17.04**
16	× S-19/22	-0.50	1.20	15.60**	0.16**	0.07	0.42*	0.32	1.23	17.99**
17	× S-19/23	1.25	-0.55	-0.16	-0.05	1.51**	-0.32	-0.18	2.94	-6.77
18	× S-19/24	-0.87	0.20	4.79	0.05	1.11**	-0.28	-0.49	3.08	-0.25
19	× S-19/25	0.25	0.70	0.25	-0.02	-2.78**	-0.25	-0.49	0.11	-4.39
20	× S-19/27	-1.25	-0.80	-12.91**	-0.03	-0.75	-0.44*	0.10	-4.29*	-8.13
21	DHLB-24A × S-19/16	0.92	0.45	1.22	-0.16**	0.08	0.70**	-0.59*	-6.76**	1.81
22	× S-19/17	-1.20	-0.80	-8.94**	0.02	-0.02	-1.29**	-0.96**	3.02	-9.61
23	× S-19/18	-0.75	-1.80	0.39	-0.03	-0.82*	0.27	-1.27**	-2.12	1.23
24	× S-19/20	0.05	-0.80	1.97	0.02	-1.09**	-0.13	-1.92**	-2.13	-1.24
25	×S-19/21	-1.95*	-1.30	-0.59	0.06	-0.21	-0.94**	-0.51	-1.36	-2.60
26	×S-19/22	2.55**	1.70	-7.10*	0.10*	0.36	0.31	2.03**	3.94	-6.90
27	×S-19/23	-0.70	-0.05	1.74	-0.00	0.33	0.03	-0.32	-6.41**	-1.03
28	×S-19/24	0.17	-0.30	7.95*	0.15**	-0.13	1.00**	2.61**	3.73	25.37**
29	×S-19/25	-0.70	0.20	-3.91	0.01	0.96*	-0.14	1.51**	-2.74	-4.50
30	×S-19/27	2.80**	2.70*	7.28*	-0.17**	0.56	0.17	-0.57*	2.84	-2.55
31	DHLB27A× S-19/16	1.07	-0.65	-2.57	-0.15**	-0.15	0.10	0.61*	1.48	2.21
32	×S-19/17	-1.55*	0.10	3.49	-0.15**	0.33	0.46**	-0.64*	-1.27	-6.55
33	×S-19/18	2.70**	2.10	7.32*	0.22**	1.17**	-0.06	0.85**	4.31*	12.74*
34	×S-19/20	-0.80	1.10	8.33*	0.24**	1.19**	0.22	0.34	4.10*	7.49
35	×S-19/21	1.20	-0.40	-7.55*	-0.12**	-0.72	0.11	0.16	1.85	-0.88
36	×S-19/22	-0.30	-2.40	-5.51	-0.07	-1.13**	-0.18	-0.25	-5.97*	-3.52
37	×S-19/23	0.95	-0.15	5.57	0.08*	-0.63	0.05	0.01	4.02*	8.60
38	×S-19/24	-0.18	-0.40	4.65	-0.19**	-0.10	-0.18	0.25	-6.76**	-13.11*
39	×S-19/25	-2.05**	2.10	-0.61	0.01	2.22**	0.33	-1.60**	1.81	0.93
40	×S-19/27	-1.05	-1.40	-13.12**	0.12**	-2.20**	-0.86**	0.28	-2.50	-7.91
	SE	0.75	1.25	3.18	0.04	0.40	0.17	0.26	2.34	5.44
	CD at 5%	1.51	2.54	6.44	0.08	0.81	0.34	0.52	4.74	11.00
	CD at 1%	2.03	3.40	8.62	0.11	1.09	0.45	0.70	6.34	14.73

*,** denote significant at 5% and 1% level respectively

Conclusion

In the present investigation, DHLB-27A and S-19/18 were potential parents for grain yield/plant. Therefore, it offered the best possibilities for cross DHLB-27A x S-19/18 was best specific combiner for grain yield per plant. They produced significant and desirable SCA effects and heterosis for most of the traits studied indicating potential for exploiting hybrid vigour in breeding programme.

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