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Research Article

Heterosis and Combining Ability Studies for Yield and Yield attributing characters in Finger millet (*Eleusine coracana (L.)* Geartn.)

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Abstract:
Heterosis and combining ability for yield and yield attributing characters were studied in finger millet through Line x Tester mating design using four lines and four testers. Combining ability analysis showed the predominant role of non-additive gene action for all the characters studied. The lines GE 4596 and GPU 28 and the testers L 5 and GPU 69 had recorded high *per se* and *gca* for yield and most of the yield contributing characters studied. The hybrid GE 4596 x L 5 and GE 4596 x GPU 69 had significant and superior per se performance for grain yield per plant, straw yield per plant, finger length, peduncle length, number of fingers per ear, culm thickness and number of productive tillers per plant. The hybrid GE 4596 x L 5 exhibited high *sca* effect for plant height , number of productive tillers per plant, finger length, peduncle length, days to 50per cent flowering, straw yield per plant, grain yield per plant and test weight. Studies on specific combining ability effects, indicates that the crosses viz., GE 4596 x L 5, GE 6216 x GPU 48 and GE 4906 x GPU 48 have significant *sca* effects for most of the characters. The hybrids, GE 4596 x L 5, GE 4596 x GPU 69 and GPU 28 x L 5 were from parents with high x high *gca* and GE 4596 x GE 5095, GE 6216 x GPU 69, GE 4906 x GPU 69 and GPU 28 x GE 5095 were from parents with high x low *gca* combinations. Thus, six crosses are suggested for realization of transgressive segregants in F_2 and subsequent generations. The five hybrids *viz.,* GE 4596 x L 5, GE 4596 x GE 5095, GPU 28 x L 5, GPU 28 x GE 5095 and GE 4906 x GE 5095 showed significant heterosis for most of the traits over their parents.
Key words: Finger millet, Heterosis, Combining ability, Transgressive segregants

Introduction

Finger millet (*Eleusine coracana (L.) Geartn.)* ranks first both in area and production among the 'Nutri-cereals' occupying 2.00 m.ha in India with the highest productivity in the state of Karnataka. Its nature of low input requirement in terms of labour, technology, costs and high drought resistance and long storage life makes it a pro-poor and marginal farmers' crop. Its small seeds can be stored safely for as long as 50 years without pest infestation, which makes it a traditional component of farmers' risk mitigation strategies in drought prone regions. It is highly valued as a reserve food in times of famine. Despite all these merits, this crop has been neglected from the main stream of crop improvement programme.

Finger millet is essentially a self pollinated crop. Being a food grain crop, yield improvement is the major goal in varietal improvement. Recombination breeding is the major approach adopted in finger millet improvement. Information on different traits of interest, especially their genetic control is a pre-requisite for planning the genetic improvement strategies. Combining ability analysis is usually employed to identify the desirable parents and to study the nature of genetic variation. Finger millet is a highly self pollinated crop and hybridization in this crop is restricted due to the small flower size which makes emasculation a difficult task. In recent years, in spite of persistent efforts, the newly evolved varieties are not showing much yield advantage over the varieties bred and released in earlier years. Scope for the exploitation of hybrid vigour will depend on the direction and magnitude of heterosis, biological feasibility and the type of gene action involved. Heterosis has been exploited extensively in crop production and has been a powerful force in the evolution of plants.

Material and methods

Four lines were crossed to four testers in a line x tester mating design in kharif, 2008, to generate hybrids by following hot water treatment for emasculation then contact method of crossing. Crossed seeds along with their parents were sown in nursery during *kharif,* 2009. The hybrids were first identified in the nursery using purple plant pigmentation as marker. All the eight parents (4 lines and 4 testers) together with 16 crosses were evaluated during *kharif,* 2009. Each genotype was grown in a single row of 3 m length with a spacing of 30 cm between rows and 10 cm apart within the row adopting randomized block design and replicated twice. The data were recorded on plant height, number of fingers per ear, number of productive tillers per plant, finger length, finger width, culm width, peduncle length, days to 50 per cent flowering, days to maturity, straw yield per plant, grain yield per plant and test weight on five randomly selected plants. The combining ability analysis was done according to Kempthorne (1957). The magnitude of heterosis was estimated over mid parent and better parent.

Results and discussion

The analysis of variance revealed significant differences among the parents as well as crosses for all the traits. Higher level of significance in the variance of parents *vs* hybrids for all the characters clearly indicated the existence of significant level of average heterosis in the hybrids. Analysis of variance for combining ability revealed that the mean squares due to testers showed significant differences for plant height, peduncle length, straw yield per plant and grain yield per plant. This indicated that there was a good level of genetic difference brought out by the testers. The variance due to line x tester interaction was significant for all the characters studied (Table 1). Non additive gene action was noticed for all the characters studied. The results support the findings of Tamilcovane (1994), Madhusudhan et al. (1995) and Patel (1994).

The combining ability studies of the parents had brought out the parents with high gca for different traits. The line GE 4596 showed high *gca* for plant height, number of fingers per ear, number of productive tillers per plant, finger length, days to maturity, straw yield per plant and grain yield per plant. The line, GPU 28 showed high *gca* for finger length, finger width, culm width, peduncle length and days to 50 per cent flowering. The tester, L 5 was identified for high *gca* effects for straw yield and grain yield. The tester, GPU 69 showed high *gca* effects for plant height, number of fingers per ear, finger length, culm width, days to maturity, straw yield per plant and grain yield per plant (Table 2). Considering the overall assessment of yield components for high *gca* and *per se* performance, a close correspondence between mean performance and gca effect was observed among parents. The lines, GE 4596andGPU 28 and the testers, L 5 and GPU 69 had recorded high *per se* and *gca* for most of the yield contributing characters studied. These parents might be utilized in the hybridization programme for selecting superior recombinants. Tamilcovane (1994) and Ravikumar (1986) also identified this kind of good general combiners in finger millet.

Specific combining ability is the deviation from the performance predicted under general combining ability. The *sca* was due to non-additive genetic interactions. The hybrid, GE 4596 x L 5 possessed high *sca* effect for plant height, number of tillers per plant, finger length, peduncle length, straw yield per plant, grain yield per plant and 1000 grain weight. The hybrid, GE 4906 x GPU 48 exhibited high *sca* effect for plant height, number of fingers per ear, finger length, finger width, culm width, grain yield per plant and 1000 grain weight. Combination of favorable genes from the parents for the corresponding traits might have resulted in high *sc*a effects. In the present study, hybrids were identified with significant and high *sca* effects for different characters. Many of these hybrids were from either one of the parents with high *gca* or parents with low x low general combiners. Hence it forms the evidence that the parents with high or low *gca* will have greater probability to have good complementarily with other parents. Among 16 hybrids developed, per cent heterosis over mid parent and better parent was negatively significant in most of the hybrids except in crosses, GE 6216 x GPU 69 and GE 6216 x GE 5095 for days to 50 per cent flowering and except GE 6216 x GPU 69 and GE 4906 x GE 5095 for days to maturity suggesting the involvement of dominant gene action with negative effects. The earlier reports suggest that early types can be obtained from crosses which record negative heterosis. Similar results were obtained by Konstantinov and linnik (1985) and Ramesh (1990) in proso millet. Significant level of heterosis over mid parent and better parent have been observed for the characters like plant height, number of productive tillers per plant, straw yield per plant and grain yield per plant.

For exploiting hybrid vigor, the components like *per se* performance, sca effects and the extent of heterosis of hybrids are important. Selection based on any of these criteria alone may not be effective. So selection must be based on all the three parameters. In the present study, the hybrids were also evaluated on the basis of above said three parameters. Among the 16 hybrids studied GE 4596 x L 5 and GE 4596 x GPU 69 were identified as the best crosses since they possessed desirable *per se* performance, *sca* and mid parent heterosis for plant height, number of productive tillers per plant, straw yield per plant and grain yield per plant (Table 4). From this study, it can be concluded that the non additive gene action favouring hybridization to some extent and the crosses, GE 4596 x L 5 and GE 4596 x GPU 69 are the best crosses for grain yield and most of the yield contributing characters.

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Table 1. Analysis of variance for combining ability

Characters	Replication df=1	Lines df=3	Testers df=3	Line vs Testers df=9	Error df=15
Plant height (cm)	3.060	504.772	54.917**	49.472**	0.533
Number of fingers per ear	0.061	5.861	0.501	0.353**	0.13
Number of productive tillers per plant	0.031	0.254	0.117	0.187**	0.009
Finger length (cm)	0.002	3.76	0.944	0.612**	0.026
Finger width (cm)	0.000	0.01	0.007	0.017**	0.002
Culm width (cm)	0.000	0.023	0.01	0.013**	0.002
Peduncle length (cm)	0.037	187.42	9.696*	21.812**	0.765
Days to 50% flowering	0.005	4.952	3.298	2.587**	0.874
Days to maturity	0.138	13.5	5.144	1.406**	1.012
Straw yield per plant g)	8.100	710.74	252.457**	113.784**	2.147
Yield per plant (g)	0.644	262.42	55.542**	30.338**	1.037
1000-seed weight (g)	0.006	0.197	0.021	0.062**	0.001

* Significant at 5% level ** Significant at 1% level

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Table 2. Estimates of gca effects for different traits in parents

Parents	Plant height (cm)	Number of fingers per ear	Number of productive tillers per plant	Finger length (cm)	Finger width (cm)	Culm width (cm)	Peduncle length (cm)	Days to 50% flowering	Days to maturity	Straw yield per plant (g)	Grain yield per plant (g)	1000-grain weight (g)
GE 4596	9.88 **	0.91 **	0.19 **	0.59 **	-0.01 ns	0.03 *	-2.03 **	0.54 ns	-1.72 **	12.37 **	8.21 **	-0.05 **
GE 6216	-1.58 **	-0.89 **	0.09 *	-0.05 ns	-0.04 *	-0.08 **	0.27 ns	0.74 *	0.36 ns	-7.31 **	-3.69 **	0.23 **
GE 4906	1.07 **	0.53 **	-0.21 **	-0.95 **	0.01 ns	0.01 ns	-4.80 **	-0.31 ns	1.41 **	2.34 **	-0.35 ns	-0.14 **
GPU 28	-9.38 **	-0.54 **	-0.08 *	0.40 **	0.04 *	0.03 *	6.56 **	-0.96 *	-0.05 ns	-7.40 **	-4.16 **	-0.03 **
L 5	-1.70 **	0.06 ns	0.07 ns	-0.25 **	0.01 ns	-0.00 ns	-0.78 *	0.04 ns	-0.17 ns	1.97 **	1.04 *	0.01 ns
GPU 69	1.13 **	0.31 *	0.07 ns	0.44 **	0.02 ns	0.05 **	-0.97 **	0.34 ns	0.88 *	4.57 **	2.55 **	-0.01 ns
GE 5095	3.13 **	-0.29 *	-0.18 **	0.10 ns	0.02 ns	-0.00 ns	1.41 **	0.54 ns	0.30 ns	-8.20 **	-3.64 **	-0.06 **
GPU 48	-2.57 **	-0.07 ns	0.04 ns	-0.30 **	-0.04 *	-0.04 *	0.33 ns	-0.91 *	-1.02 *	1.67 **	0.05 ns	0.06 **

* Significant at 5% level ** Significant at 1% level

Table 3. Specific combining ability effects of crosses for yield and yield attributes

Crosses	Plant height (cm)	Number of fingers per ear	Number of productive tillers per plant	Finger length (cm)	Finger width (cm)	Culm width (cm)	Peduncle length (cm)	Days to 50% flowering	Days to maturity	Straw yield per plant (g)	Grain yield per plant (g)	1000-grain weight (g)
GE-4596 X L-5	4.78**	-0.03	0.16*	0.52**	0.02	-0.01	1.98**	1.59*	-0.68	5.08**	4.05**	0.09**
GE-4596 X GPU 69	-1.76**	0.12	0.36**	-0.02	-0.04	0.04	-1.98**	-1.21	0.27	1.48	2.07**	-0.05**
GE-4596 X GE 5095	2.54**	0.32	-0.39**	0.12	0.01	-0.01	-0.86	-0.31	0.55	-10.65**	-4.94**	0.15**
GE-4596 X GPU 48	-5.56**	-0.41	-0.12	-0.63**	0.02	-0.02	0.87	-0.06	-0.13	4.08**	-1.18	-0.19**
GE 6216 X L-5	2.84**	-0.03	-0.04	-0.04	-0.04	-0.05	-2.92**	-0.31	-0.36	-1.94	-0.83	0.00
GE 6216 X GPU 69	0.70	0.12	-0.34**	0.57**	0.04	0.05	-3.38**	1.29	0.19	2.16	1.11	0.14**
GE 6216 X GE 5095	0.55	0.12	0.11	0.11	0.14**	0.10**	5.64**	-0.11	-0.32	6.42**	2.70**	-0.07**
GE 6216 X GPU 48	-4.10**	-0.21	0.28**	-0.64**	-0.14**	-0.11**	0.67	-0.86	0.49	-6.64**	-2.99**	-0.08**
GE 4906 X L-5	-4.66**	-0.36	-0.04	-0.44**	0.01	0.02	-0.10	-0.26	0.19	-4.89**	-2.17**	-0.20**
GE 4906 X GPU 69	0.85	0.19	0.26**	-0.08	-0.01	-0.03	3.24**	-0.76	-1.06	6.61**	1.98**	-0.09**
GE 4906 X GE 5095	-4.85**	-0.51	-0.09	0.01	-0.11**	-0.08*	-0.98	-0.36	1.03	-3.83**	-2.34**	-0.04*
GE 4906 X GPU 48	8.65**	0.67**	-0.12	0.51**	0.11**	0.10**	-2.16**	1.39	-0.16	2.11	2.53**	0.33**
GPU 28 X L-5	2.96**	0.42	-0.07	-0.04	0.02	0.04	1.04	-1.01	0.85	1.75	-1.06	0.11**
GPU 28 X GPU 69	0.20	-0.43	-0.27**	-0.48**	0.01	-0.06	2.13**	0.69	0.60	-10.25**	-5.16**	0.00
GPU 28 X GE 5095	1.75**	0.07	0.38**	-0.24	-0.04	-0.01	-3.80**	0.79	-1.26	8.06**	4.58**	-0.04*
GPU 28 X GPU 48	1.00	-0.06	-0.04	0.76**	0.02	0.03	0.63	-0.46	-0.20	0.45	1.64*	-0.06**

* Significant at 5% level ** Significant at 1% level

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Table 4. Per cent heterosis over mid parent (MP) and better parent (BP) for yield and yield attributes in finger millet

Crosses	**CHARACTERS**											
	Plant height (cm)		Number of fingers per ear		Number of productive tillers per plant		Finger length (cm)		Finger width (cm)		Culm width (cm)	
	MP	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**
GE-4596 X L-5	13.10**	0.45	0.56	-1.10	29.41**	22.22**	-1.27	-14.75**	-6.98*	-16.67**	-6.98*	-13.04**
GE-4596 X GPU 69	6.52**	-2.90**	3.30	0.00	71.43**	50.00**	2.25	-13.11**	-2.56	-5.00	4.76	0.00
GE-4596 X GE 5095	18.58**	2.81**	9.76**	2.27	-15.15*	-17.65*	-1.59	-15.30**	2.56	0.00	-4.76	-9.09*
GE-4596 X GPU 48	4.24**	-9.71**	4.29	-3.41	18.75**	18.75*	-13.73**	-27.87**	5.56	0.00	0.00	-5.00
GE 6216 X L-5	7.01**	1.04	-11.11**	-20.88**	22.58**	5.56	4.35	-0.75	-18.18**	-25.00**	-22.73**	-26.09**
GE 6216 X GPU 69	4.81**	1.77	-7.88**	-19.15**	28**	23.08*	27.42**	23.44**	0.00	0.00	-6.98*	-9.09*
GE 6216 X GE 5095	12.70**	3.69**	-4.76	-7.89	20**	5.88	12.70**	7.58*	10.00*	10.00*	-6.98*	-9.09*
GE 6216 X GPU 48	1.13	-7.06**	-5.48	-8.00	51.72**	37.50**	-2.06	-3.25	-18.92**	-25.00**	-23.08**	-28.57**
GE 4906 X L-5	-3.02**	-12.04**	-6.201	-8.79*	-3.03	-11.11	-12.40**	-20.30**	-4.76	-16.67**	-6.98*	-13.04**
GE 4906 X GPU 69	2.96**	-4.09**	1.11	-3.19	40.74**	26.67**	7.17*	-0.78	5.26	0.00	-4.76	-9.09*
GE 4906 X GE 5095	4.41**	-7.61**	-3.70	-9.30*	-18.75**	-23.53**	1.24	-7.58*	-5.26	-10.00*	-14.29**	-18.18**
GE 4906 X GPU 48	12.92**	-0.19	14.29**	6.98	-3.23	-6.25	6.90*	0.81	20.00**	16.67**	10.53*	5.00
GPU 28 X L-5	-2.31*	-2.45*	-4.76	-12.09**	6.25	-5.56	4.44	2.92	-4.55	-12.50	0.00	-8.70*
GPU 28 X GPU 69	1.64	-1.10	-13.45**	-21.28**	15.38*	7.14	10.19**	6.57*	5.00	5.00	-2.44	-9.09*
GPU 28 X GE 5095	11.88**	8.68**	-4.58	-5.19	22.58**	11.76	7.06*	5.11	0.00	0.00	-2.44	-9.09*
GPU 28 X GPU 48	4.26**	1.17	-2.63	-3.90	13.33*	6.25	20.00**	13.87**	8.11*	0.00	8.11**	5.26

* Significant at 5% level ** Significant at 1% level

Table 3 Cont………..

Crosses	CHARACTERS											
	Peduncle length (cm)		Days to 50% flowering		Days to maturity		Straw yield per plant (g)		Grain yield per plant (g)		1000-grain weight (g)	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
GE-4596 X L-5	38.17**	36.57**	-2.83*	-3.46*	-5.14**	-5.36**	96.46**	47.34**	63.12**	62.31**	-0.45	-1.78*
GE-4596 X GPU 69	9.00	-1.85	-6.73**	-7.07**	-3.42**	-3.51**	106.50**	44.81**	77.96**	59.9**	-1.48*	-6.42**
GE-4596 X GE 5095	-4.73	-25.00**	-3.96**	-5.48**	-4.23**	-4.67**	25.93**	-18.23**	17.80*	-6.27	7.44**	-2.24**
GE-4596 X GPU 48	18.47**	4.61	-7.55**	-7.88**	-5.68**	-5.72**	108.42**	44.05**	49.22**	31.08**	-6.68**	-8.40**
GE 6216 X L-5	-8.65	-24.3**	-3.69**	-4.68**	-2.69**	-2.69**	50.90**	43.18**	13.04	-21.01**	6.41**	6.38**
GE 6216 X GPU 69	-6.88	-28.35**	-1.18	-2.47*	-1.34	-1.48	101.58**	73.64**	60.42**	19.81*	14.29**	10.01**
GE 6216 X GE 5095	31.42**	21.81**	-1.72	-1.79*	-2.90**	-3.57**	75.74**	35.00**	47.07**	22.46	11.02**	2.30**
GE 6216 X GPU 48	11.77**	4.98	-6.87**	-8.74**	-2.96**	-3.23**	42.86**	20.45*	8.50	-17.55	6.21**	5.69**
GE 4906 X L-5	-12.97	-18.85**	-6.96**	-7.76**	-1.57	-1.93*	46.78**	18.27**	-2.63	-10.89	-14.04**	-17.7**
GE 4906 X GPU 69	25.18**	6.97	-7.51**	-8.05**	-1.89*	-2.12*	117.01**	61.92**	43.96**	41.77**	-8.01**	-15.09**
GE 4906 X GE 5095	-27.74**	-40.43**	-5.49**	-7.18**	-1.06	-1.37	31.97**	-9.91	-9.57	-22.26*	-4.49**	-15.43**
GE 4906 X GPU 48	-31.94**	-36.52**	-6.89**	-7.02**	-2.95**	-3.04**	89.45**	39.01**	35.24**	29.88**	2.68**	-2.17**
GPU 28 X L-5	38.49**	2.75	-7.10**	-8.19**	-3.03**	-4.08**	35.65**	9.69	-16.17*	-24.56**	2.14**	1.95*
GPU 28 X GPU 69	53.04**	6.88	-4.42**	-5.81**	-2.43**	-3.36**	7.31	-19.69**	-22.4**	-22.64*	2.30**	-1.38
GPU 28 X GE 5095	-2.71	-9.40*	-2.76*	-2.98**	-5.19**	-5.58**	42.69**	-2.34	14.86	0.32	3.82**	-4.19**
GPU 28 X GPU 48	28.69**	5.96	-8.64**	-10.60**	-5.03**	-5.81**	42.25**	4.69	7.44	5.06	-0.84	-1.17

* Significant at 5% level ** Significant at 1% level