

**RESEARCH ARTICLE :**

# Combining ability and gene action for grain yield and nutritional traits in barnyard millet (*Echinochloa frumentacea* (Roxb.) Link)

■ V.G. RENGANATHAN, S.M. IBRAHIM, C. VANNIARAJAN, J. PRABAKARAN AND P. ARUNACHALAM

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**SUMMARY :** Twenty four cross combinations from six lines with four testers were studied along with parents for combining ability and gene action in barnyard millet. The SCA variance was greater in magnitude than GCA variance for all the six characters studied indicates the predominance of non additive gene action. Amongst the ten parental lines, ACM 10-145, CO 1, CO 2, ACM 12, PMK 331 and PMK 332 were the best general combiners for grain yield along with nutritional traits. Out of 24 cross combinations, CO 2 x ACM 12, ACM 12-110 x PMK 331, CO 1 x PMK 331 and ACM 10-145 x ACM 12 were adjudged as the best specific combiners for nutritional traits along with grain yield. This result gives an idea that heterosis could be exploited in self pollinated crops like barnyard millet. However, male sterile system have to be identified as reported in foxtail millet to exploit heterosis. At present, recombination breeding followed by selection may be useful for improve these nutritional traits in barnyard millet.

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## **BACKGROUND AND OBJECTIVES**

Small millets supports for livelihood and food security to the millions of local inhabitants of tropical and subtropical regions. They are rich in micronutrients like calcium, iron, phosphorous, vitamins, and sulphur containing amino acids which ensure the alleviation of malnutrition. Among minor millets, grains of barnyard millet contain high profile of protein, carbohydrate, crude fibre, fat, ash and

essential amino acids than rice. Dietary fibre which is present as soluble and insoluble form is proved to play an important role in the management of metabolic disorders and life style diseases like diabetes mellitus, hyperlipidemia and colon cancer. The glycemic index (GI) of the food products prepared from barnyard millet is very low, and are highly suitable for diabetic patients (Ugare *et al.*, 2014). The information on combining

**Author for correspondence :**

**V.G. RENGANATHAN**  
Department of Plant  
Breeding and Genetics,  
Agricultural College and  
Research Institute,  
MADURAI (T.N.) INDIA  
Email : [vgrenga@gmail.com](mailto:vgrenga@gmail.com)

See end of the article for  
authors' affiliations

ability and gene action on nutritional traits of barnyard millet is not available. Hence, the present study was carried out to acquire information on combining ability and gene action involved in some important nutritional traits in barnyard millet. Combining ability analysis helps to identify suitable parents and to frame the breeding strategy effectively based on combining ability and nature of gene action for improvement of barnyard millet.

## RESOURCES AND METHODS

The research was conducted in the experimental area of the Plant Breeding and Genetics farm at Agriculture College and Research Institute, Madurai during *Rabi* season in 2013. The experimental materials comprised of six barnyard millet lines *viz.*, CO 1, CO 2, ACM 10-082, ACM 12-110, ACM 10-145, ACM 10- and four testers *viz.*, ACM 11, ACM 12, PMK 331 and PMK 332 were crossed in “line × tester” mating design of Kempthorne, 1957 to obtain 24 crosses. These cross combination along with ten parents were evaluated in a Randomized Block Design (RBD) in three replications during *Kharif* 2014. The row to row spacing was 30 cm and plant to plant spacing was given by 10 cm. Recommended agronomic practices were followed for good crop condition. In each replication randomly five competitive plants were selected and observations were recorded for grain yield and nutritional traits namely, carbohydrate, protein crude fibre, iron and zinc content. For nutritional analysis, the grain sample was fine grained and powdered form was taken for all nutritional estimations. The mean values of individual traits were used in combining ability analysis based on the method

of Kempthorne (1957).

## OBSERVATIONS AND ANALYSIS

In the present investigation, genotypes (lines, testers) and line x tester interaction were significant for all the six traits of barnyard millet. It indicated the presence of good genetic diversity among the lines, testers and male x female interaction and thus, greater contribution by these characters towards combining ability (Prasad *et al.*, 2015). The ratio between  $\sigma^2_{GCA}$  and  $\sigma^2_{SCA}$  was less than unity which pointed out the preponderance of non-additive gene action for the inheritance of the assessed traits. These findings are in concordance with Tariq *et al.* (2014) for crude fibre and protein in sorghum, Lahane *et al.* (2014) for protein in maize, Indhubala *et al.* (2010) for yield in sweet sorghum, Rosamma and Vijayakumar (2005) for grain yield plant<sup>-1</sup> (rice), Adilakshmi and Upendra (2014) for grain yield, iron and zinc content in rice. Due to non-additive gene action, there is a possibility of exploiting these traits by heterosis breeding in barnyard millet. The hybrid seed production through manual crossing is difficult due to small florets and male sterile source lines yet to be identified in barnyard millet. However, report on availability of male sterile lines in foxtail millet (Wang, 1991) would open the way for identification of male sterile system in barnyard millet. In the present circumstance and considering the nature of gene action recombination breeding followed by selection or postponing the selection to later generation in later segregating generation or intermating segregants and selection may helps to improve these nutritional traits in barnyard millet.

**Table 1 : ANOVA for combining ability and genetic variance for nutritional traits in barnyard millet**

Source of variation	df	CHO (g)	PR (g)	CF (g)	Fe (mg)	Zn (mg)	GY (g)
<b>Mean sum of square</b>							
Replications	2	0.58	0.26	0.02	0.14	0.10	1.19*
Lines	5	24.16*	4.63*	4.46*	4.33*	5.47*	69.91*
Testers	3	66.39*	7.43*	7.73*	36.26*	2.73*	114.38*
L x T interaction	15	22.57*	4.24*	3.25*	4.89*	1.44*	122.63*
Error	23	0.34	0.14	0.14	0.11	0.06	0.47
<b>Estimates of variance</b>							
<sup>2</sup> <sub>l</sub>	-	0.13	0.03	0.10	-0.05	0.34	-4.39
<sup>2</sup> <sub>t</sub>	-	2.43	0.18	0.25	1.74	0.07	-0.46
<sup>2</sup> <sub>GCA</sub>	-	0.30	0.02	0.04	0.20	0.05	-0.63
<sup>2</sup> <sub>SCA</sub>	-	7.40	1.36	1.04	1.59	0.46	40.72
<sup>2</sup> <sub>GCA</sub> <sup>2</sup> <sub>SCA</sub>	-	0.04	0.01	0.04	0.13	0.11	-0.02

CHO –carbohydrate, PR- protein, CF-crude fibre, Fe-Iron, Zn-zinc, GY-grain yield, \* indicate significance of value at P=0.05, respectively.

The estimates of general combining ability (*gca*) effects of 10 parents and specific combining ability (*sca*) effects of best crosses (top five positive significant with *per se*) for six traits are presented in Table 2 and 3, respectively.

The parents, CO2, ACM 12-110, ACM 12 and PMK 332 showed significant positive *gca* effects for grain yield can be used as good general combiners. The *gca* effects together with relative *per se* performance is useful for selecting desirable parent with favorable genes for improvement of yield and related traits (Prasad *et al.*, 2015). Among the crosses, CO 2 x ACM 12, CO 2 x PMK 331, ACM 12-110 x ACM 12, ACM 10-145 x PMK 332, ACM 12-110 x PMK 332 were found to be as good specific combiners for grain yield since they are having high positive significant *sca* effects. This finding was concomitant by Pawar *et al.* (2015), where he reported that the parents, which possessed higher *gca* effects for grain yield and its components were also good in their mean performance. Out of 24 cross combinations, the cross CO 2 x ACM 12 obtained from good x good general combiners, exhibited significant positive *sca* effect and high *per se* performance. Hence, this cross may be considered to be the best for this trait through heterosis breeding or postponed to selection in segregating generation.

For carbohydrate, ACM 10-145 alone recorded significant positive *gca* effects and CO 1 x PMK 331, CO 2 x PMK 332, ACM 10-082 x ACM 11, ACM 10-

145 x ACM 11 and ACM 10-145 x ACM 12 cross combinations were found to be good specific combiners. The cross combination CO 2 x PMK 332 (low x good combiner) showed high *per se* performance and positive significant *sca* effect.

The promising genotypes for protein are CO 2, ACM 10-082 and ACM 12 exhibited significant positive *gca* effects and promising cross combinations with good specific combiners (*sca* effect) are CO 1 x ACM 11, CO 1 x ACM 12, CO 2 x ACM 12, ACM 12-110 x PMK 331 and ACM 10-145 x PMK 331. The cross CO 2 x ACM 12 (good x good combiner) recorded the best *per se* performance for the trait protein. This similar type of good x good combiner yield high *sca* effect for protein content in rice was reported by Adilakshmi and Upendra (2014).

Significant positive *gca* effects for crude fibre were recorded in parents CO 1, CO 2 and ACM 12. High *sca* effects were observed in cross combinations of CO 1 x ACM 11, CO 1 x PMK 331, ACM 10-082 x ACM 12, ACM 12-110 x PMK 331 and ACM 10-145 x ACM 12 for crude fibre. The cross combination CO 1 x PMK 331 (good x average combiner) showed high mean value for the trait crude fibre.

The genotypes CO 2, ACM 10-145 and PMK 332 showed significant positive *gca* effects for iron content. The cross combinations CO 1 x ACM 11, CO 1 x PMK 332, CO 2 x ACM 12, CO 2 x PMK 331 and ACM 10-082 x ACM 12 showed high positive significant *sca*

**Table 2 : The *gca* effects and *gca* status of parents for nutritional traits in barnyard millet**

Parents	CHO (g)	Status of <i>gca</i>	PR (g)	Status of <i>gca</i>	CF (g)	Status of <i>gca</i>	Fe (mg)	Status of <i>gca</i>	Zn (mg)	Status of <i>gca</i>	GY (g)	Status of <i>gca</i>
<b>Lines</b>												
CO1	0.23 ns	A	-0.31**	L	0.84**	G	-0.67 **	L	-0.35 **	L	-2.74 **	L
CO2	-1.36 **	L	0.72**	G	0.66**	G	1.01 **	G	1.31 **	G	4.36 **	G
ACM 82	0.23 ns	A	0.72**	G	-0.53**	L	0.02 ns	A	-0.16 *	L	-1.40 **	L
ACM 12-110	-1.53 **	L	-0.36**	L	-0.50**	L	-0.46 **	L	-0.51 **	L	0.56 **	G
ACM 10-145	2.40 **	G	0.04 ns	A	-0.41**	L	0.31 **	G	-0.37 **	L	-0.57 **	L
ACM 10-161	0.04 ns	A	-0.81**	L	-0.07 ns	A	-0.20 *	L	0.08 ns	A	-0.21 ns	L
SE	0.17		0.11		0.11		0.10		0.07		0.20	
<b>Testers</b>												
ACM 11	-1.00 **	L	-0.48**	L	-0.86**	L	-1.00 **	L	-0.43 **	L	-1.70 **	L
ACM 12	-2.14 **	L	0.90**	G	0.73**	G	0.06 ns	A	-0.05 ns	A	1.96 **	G
PMK 331	1.03 **	G	-0.44**	L	0.06 ns	A	-1.05 **	L	-0.05 ns	A	-2.61 **	L
PMK 332	2.11 **	G	0.03 ns	A	0.06 ns	A	1.99 **	G	0.52 **	G	2.35 **	G
SE	0.14		0.09		0.09		0.08		0.06		0.16	

CHO –carbohydrate, PR- protein, CF-crude fibre, Fe-Iron, Zn-zinc, GY-grain yield, A-Average, G-good, L-low,

NS=Non-significant

\* and \*\* indicate significance of values at P=0.05 and 0.01, respectively

effects for iron. Among these, the cross CO 1 x PMK 332 (low x good combiner) showed high *per se* performance. The parents CO2 and PMK 332 showed significant positive *gca* effects for zinc. Among the crosses, CO 2 x ACM 12, ACM 10-082 x ACM 12, ACM 10-161 x PMK 331, ACM 12-110 x ACM 11 and ACM 10-161 x ACM 11 were found to be good specific combiners for zinc due to high positive significant *sca* effects. While, CO 2 x ACM 12 (good x low combiner) cross combination recorded the best performance for the trait zinc content.

The findings of present investigation are the parents CO 1, CO 2, ACM 10-145, ACM 12, PMK 331 and PMK 332 could be the better choice for improvement of

nutritional quality along with yield through hybridization followed by selection. Among cross combinations, CO 2 x ACM 12 (protein, iron and zinc) followed by ACM 12-110 x PMK 331 (protein and crude fibre), CO 1 x PMK 331 and ACM 10-145 x ACM 12 (carbohydrate and crude fibre) were adjudged as the best specific combiners along with grain yield. For majority of nutritional traits, crosses were involved with good/low or average/low combinations indicating additive x dominance type of gene interactions for expression of traits except grain yield. Similar observation was reported by Mungra *et al.* (2015) in pearl millet where most of morphological traits and grain yield are controlled by additive x dominance, dominance x dominance and additive x additive type of

**Table 3 : Specific combining ability effects of selected cross combinations for grain yield and nutritional traits in barnyard millet**

Characters	Crosses	<i>Per se</i>	<i>sca</i> effect	<i>gca</i> status of parents		Best cross for heterosis breeding
Carbohydrate (g)	CO 1 x PMK 331	71.16	2.93 **	A	G	CO 2 x PMK 332
	CO 2 x PMK 332	71.29	3.57 **	L	G	
	ACM 10-082 x ACM 11	70.71	4.50 **	A	L	
	ACM 10-145 x ACM 11	70.74	2.36 **	G	L	
	ACM 10-145 x ACM 12	69.52	2.28 **	G	L	
Protein (g)	CO 1 x ACM 11	11.25	1.21**	L	L	CO 2 x ACM 12
	CO 1 x ACM 12	12.38	0.97**	L	G	
	CO 2 x ACM 12	13.50	1.05**	G	G	
	ACM 12-110 x PMK 331	11.19	1.17**	L	L	
	ACM 10-145 x PMK 331	11.37	0.95**	A	L	
Crude fibre (g)	CO 1 x ACM 11	10.35	0.64 **	G	L	CO 1 x PMK 331
	CO 1 x PMK 331	11.64	1.00 **	G	A	
	ACM 10-082 x ACM 12	10.71	0.78 **	L	G	
	ACM 12-110 x PMK 331	10.87	1.58 **	L	A	
	ACM 10-145 x ACM 12	11.29	1.23 **	L	G	
Iron (mg)	CO 1 x ACM 11	10.22	0.60 **	L	L	CO 1 x PMK 332
	CO 1 x PMK 332	12.30	0.76 **	L	G	
	CO 2 x ACM 12	12.15	0.86 **	G	A	
	CO 2 x PMK 331	11.14	0.95 **	G	L	
	ACM 10-082 x ACM 12	11.57	1.26 **	A	A	
Zinc (mg)	CO 2 x ACM 12	10.03	0.48 **	G	L	CO 2 x ACM 12
	ACM 10-082 x ACM 12	9.12	1.05 **	L	L	
	ACM 10-161 x PMK 331	9.12	0.80**	A	L	
	ACM 12-110 x ACM 11	8.27	0.92 **	L	L	
	ACM 10-161 x ACM 11	8.34	0.40 **	A	L	
Grain yield (g)	CO 2 x ACM 12	46.38	4.20 **	G	G	CO 2 x ACM 12
	CO 2 x PMK 331	42.71	5.10 **	G	L	
	ACM 12-110 x ACM 12	42.69	4.32 **	G	G	
	ACM 10-145 x PMK 332	43.95	6.30 **	L	G	
	ACM 12-110 x PMK 332	42.50	3.72 **	G	G	
Overall						CO 2 x ACM 12

A-Average, G-good, L-low, \* and \*\* indicate significance of values at P=0.05 and 0.01, respectively

gene interactions. Hence this cross combinations can be effectively utilized for commercial exploitation of hybrid vigour for nutritional traits through heterosis breeding programme. But at present, due to lack of male sterile lines recombination breeding followed by selection is viable option for improving nutritional traits in barnyard millet along with grain yield in advancing suitable cross combinations.

#### Author's contribution :

Conceptualization and designing of the research work (V.G.Renganathan and S. M. Ibrahim); Execution of field/lab experiments and data collection (C. Vanniarajan and J. Prabakaran); Analysis of data and interpretation (J. Prabakaran); Preparation of manuscript (V.G.Renganathan and P. Arunachalam).

#### Declaration:

We authors declare that do not have conflict of interest.

Authors' affiliations :

**S.M. IBRAHIM, C. VANNIARAJAN AND P. ARUNACHALAM**, Department of Plant Breeding and Genetics, Agricultural College and Research Institute, MADURAI (T.N.) INDIA

**J. PRABAKARAN**, Department of Soils and Environment, Agricultural College and Research Institute, MADURAI (T.N.) INDIA

#### REFERENCES

**Adilakshmi, D.** and Upendra, A. (2014). Combining ability analysis for quality and nutritional traits in rice. *Internat. J. Farm Sci.*, **4**(2): 15-23.

**Indhubala, M.**, Ganesamurthy, K. and Punitha, D. (2010). Combining ability studies for quality traits in sweet sorghum

(*Sorghum bicolor* (L.) Moench). *Madras Agric. J.*, **97**(1-3): 17-20.

**Kempthorne, O.** (1957). *An Introduction to genetic statistics*. John Willey and Sons. Inc., NEW YORK, USA.

**Lahane, G.R.**, Chauhan, R.M. and Patel, J.M. (2014). Combining ability and heterosis studies for yield and quality traits in quality protein maize. *J. AgriSearch*, **1**(3): 135-138.

**Mungra, K.S.**, Dobariya, K.L., Sapovadiya, M.H. and Vavdiya, P.A. (2015). Combining ability and gene action for grain yield and its component traits in pearl millet (*Pennisetum glaucum* (L.) R. Br.). *Electron J. Plant Breed.*, **6**(1): 66-73.

**Pawar, M.B.**, Rathod, A.H. and Patel, P.S. (2015). Combining ability effects of parents and hybrids for yield and its components in pearl millet [(L.) R. Br.]. *Green Farming*, **4**: 672-676.

**Prasad, S.**, Verma, O.P., Treepathi, N., Ashish and P.K. Yadav (2015). Combining ability for yield and its contributing traits in rice (*Oryza sativa* L.) under salt affected soil. *Internat. J. Sci. Res.*, **4** (9): 1050-1054.

**Rosamma, C.A.** and Vijayakumar, N.K. (2005). Heterosis and combining ability in rice (*Oryza sativa* L.). *Indian J. Genet.*, **65** (2): 119-120.

**Tariq, S.**, Akram, Z., Shabbir, G., Khan, K.S., Mahmood, T. and Iqbal, M.S. (2014). Heterosis and combining ability evaluation for quality traits in forage sorghum (*Sorghum bicolor* L.). *SABRAO J. Pl. Br. Gen.*, **46**(2): 174-182.

**Ugare, R.**, Chimmad, B., Naik, R., Bharati, P. and Itagi, S. (2014). Glycemic index and significance of barnyard millet (*Echinochloa frumentaceae*) in type II diabetics. *J. Food Sci. Technol.*, **51**(2):392-395.

**Wang, T.** (1991). Studies and utilization of a high nuclear male sterile line in foxtail millet. *J. Hebei Agric. Univ.*, **14**:60-66.

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