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COMBINING ABILITY ANALYSIS FOR GRAIN YIELD AND ITS COMPONENT TRAITS IN PEARL MILLET (*PENNISETTUM GLAUCUM* L. R. BR.)

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ABSTRACT

The variance due to general combining ability and specific combining ability were significant except for days to maturity, suggesting the importance of both additive and non-additive gene action for the inheritance of all remaining traits. Further, the ratio of ó^{2}gca/ó^{2}sca was less than unity, revealing the predominant role of non-additive gene action in the inheritance of grain yield per plant, effective tillers per plant, earhead weight, test weight, harvest index and Zn content. For days to 50% flowering, nodes on main stem, plant height, earhead length and earhead girth σ^2gca/σ^2sca were more than unity, which indicates additive gene action was more important for controlling these traits. Based on the GCA effects, promising general combiners were identified. Among the female parents, CMS lines JMSA 20172, ICMA 98222 and ICMA 98444 demonstrated strong general combining abilities across various characters and environments. Among the testers, J-2562, J-2563 and J-2582 emerged as good general combiners for grain yield per plant and one or more component characters, establishing them as potential sources of desirable genes for achieving higher yields directly or indirectly through various traits. Among the hybrids, the best three specific combiner hybrids for grain yield per plant pooled over environments were ICMA 11222 x J-2500, JMSA 20172 x J-2563 and ICMA 99222 x J-2608.

Key words : General Combining Ability, Specific Combining Ability and Gene Action.

Introduction

The pearl millet is an annual, tillering diploid (2n = 2x = 14) crop plant that belongs to the family *Poaceae* and subfamily *Paniceidae* and is believed to have originated in Africa. The inflorescence of pearl millet is a compound terminal spike called a panicle. The seed of pearl millet is classified as a caryopsis. The root system of pearl millet is of the typical monocotyledonous type, comprising seminal or primary roots, adventitious roots and crown or collar roots. It is a highly cross-pollinated crop with protogynous flowering and mainly wind-borne pollination mechanism, favoring the development of hybrids and commercial exploitations of heterosis (Gupta *et al.*, 2024).

Pearl millet is a highly nutritious cereal compared to commonly consumed staple crops such as wheat, rice, maize and sorghum. This grain boasts a rich nutritional profile, abundant in carbohydrates, proteins, fats, fibers, resistant starch, vitamins, antioxidants and crucial micronutrients like iron and zinc. Moreover, its essential amino acid composition is more balanced than maize or sorghum (Krishnan and Meera, 2018). It is an essential staple food for millions, particularly in regions where other cereal crops face challenges due to harsh environmental conditions. Not limited to just its grains, pearl millet also provides a substantial amount of dry matter in the form of forage and stover during harvest. This additional yield is crucial in resource-scarce agricultural settings, serving as valuable animal feed. Recognizing the importance of pearl millet, there is a growing interest in improving its productivity and yield potential through comprehensive breeding strategies.

Combining ability refers to the ability of a parent to contribute desirable traits to its offspring when crossed with different parents. Through careful combining ability analysis, breeders can select the most compatible parental combinations likely to produce superior hybrids. Consequently, the current investigation has been designed to evaluate the magnitude of genetic variance components by analyzing combining ability, encompassing both the general combining ability of parents and the specific combining ability of hybrids.

Materials and Methods

The crossing programme was carried out at the Regional Research Station, Anand Agricultural University, Anand, in the late *rabi* of 2021-2022 using 6 lines and 9 testers (Table 1) using Line x Tester mating design. A group of 69 genotypes (6 lines, 9 testers, 54 hybrids) were evaluated in a Randomized Complete Block Design with three replications in three diverse environments *viz.*, Regional Research Station, Anand Agricultural University, Anand (E_1), Agricultural Research Station, Anand Agricultural University, Jabugam (E_2) and Agricultural Research Station, Anand Agricultural University, Sansoli (E_3) during summer, 2022. The spacing between plants was maintained at 60 x 15 cm and each plot had a row length of 2 meters. The observations were recorded on five plants selected randomly for each experimental entry in each replication. The mean values per plant were computed, except for phenological traits, days to 50% flowering and days to maturity, and test weight and micronutrients (Fe and Zn content); these observations were recorded on a population and sample basis, respectively. Observations were recorded for 15 characters, which include different quantitative and qualitative characters *viz.*, grain yield per plant (g), days to 50% flowering, days to maturity, nodes on main stem, plant height (cm), effective tillers per plant, earhead length (cm), earhead girth (cm), dry earhead weight (g), test weight (g), dry fodder weight (g), panicle index (%), harvest index (%), Fe content (mgkg^{-1}) and Zn content (mgkg^{-1}). The observations for hybrids and parents were subjected to a line x tester analysis. The general combining ability effects of parents and the specific combining ability effects of different crosses were worked out using the method developed by Kempthorne (1957).

Table 1 : List of parents and their source.

S. no.	Genotypes	Source
CMS Lines (Female Parents)		
1	ICMA 04999	ICRISAT, Hyderabad
2	ICMA 11222	ICRISAT, Hyderabad
3	JMSA 20172	MPRS, JAU, Jamnagar
4	ICMA 98222	ICRISAT, Hyderabad
5	ICMA 98444	ICRISAT, Hyderabad
6	ICMA 99222	ICRISAT, Hyderabad
Testers (Male Parents)		
1	J-2372	MPRS, JAU, Jamnagar
2	J-2405	MPRS, JAU, Jamnagar
3	J-2496	MPRS, JAU, Jamnagar
4	J-2500	MPRS, JAU, Jamnagar
5	J-2532	MPRS, JAU, Jamnagar
6	J-2562	MPRS, JAU, Jamnagar
7	J-2563	MPRS, JAU, Jamnagar
8	J-2582	MPRS, JAU, Jamnagar
9	J-2608	MPRS, JAU, Jamnagar

Results and Discussion

The analysis of variance for combining ability pooled over environments revealed a highly significant difference for the environments across all traits (Table 2). The variance for the lines, testers and line × tester mean squares was significant for all traits, except for days to maturity. The variance due to general combining ability and specific combining ability were significant for all traits, except for days to maturity, suggesting the influence of both additive and non-additive gene actions in the inheritance of the remaining characteristics. Moreover, the ratio of σ^2gca/σ^2sca was less than unity for grain yield per plant, effective tillers per plant, earhead weight, test weight, harvest index and Zn content. This implies that non-additive gene action plays a predominant role in the inheritance of these traits. On the contrary, for days to 50% flowering, nodes on the main stem, plant height, earhead length and earhead girth, the ratio σ^2gca/σ^2sca was more than unity. This suggests that additive gene action is more important in controlling these traits. The similar results were reported by Gami *et al.* (2021), Patil *et al.* (2021), Suryawanshi *et al.* (2021), Athoni *et al.* (2022), Ingle *et al.* (2023), Surendhar *et al.* (2023) and Tribhuvan *et al.* (2023) for grain yield per plant; Davda and Dangariya (2018), Saini *et al.* (2018) and Patil *et al.* (2021) for days to 50% flowering; Chotaliya *et al.* (2010), Davda and Dangariya (2018) and Saini *et al.* (2018) for plant height; Gami *et al.* (2021), Patil *et al.* (2021), Ingle *et al.* (2023) and Surendhar *et al.* (2023) for effective tillers per plant; Davda and Dangariya (2018), Saini *et al.* (2018) and Patil *et al.* (2021) for earhead length; Saini *et al.* (2018) and Patil *et al.* (2021) for earhead girth; Jethva *et al.* (2011), Mungra *et al.* (2015) and Athoni *et al.* (2022) for dry earhead weight; Gami *et al.* (2021),

Table 2 : Analysis of variance (mean sum of square) pooled over environments for combining ability and components of genetic variance for different characters in pearl millet.

Source of variation	d. f.	GY	DF	DM	NMS	PH	ETP	EL	EG	EW	TW	DFW	PI	HI	FE	ZN
Environments	2	20220.48**	1661.42**	455.04**	39.88**	66760.41**	1.50**	1196.79**	96.11**	11.57*	46.28**	151593.89**	2453.35**	236.28**	583.84**	40.41**
Replications/Env	6	3.98	15.71	22.51**	1.71**	442.28**	0.11*	18.08**	0.71*	1.71	3.06**	275.03*	81.74	14.01	19.11**	3.82**
Line (L)	5	643.08**	557.73**	2.86	23.89**	16020.58**	1.11**	451.77**	19.33**	910.06**	12.15**	12817.45**	683.55**	552.08**	2623.17**	532.22**
Tester (T)	8	657.97**	124.82**	5.26	3.22**	2979.38**	0.60**	181.12**	22.75**	626.55**	6.65**	9164.52**	811.96**	375.78**	520.37**	327.27**
Line × Tester (L × T)	40	314.13**	14.97**	2.80	0.49**	379.95**	0.40**	21.35**	0.92**	62.81**	5.57**	684.64**	192.25**	63.19**	1845.60**	200.27**
L × E	10	523.35**	90.93**	4.01	1.35**	466.28**	0.28**	15.91**	3.59**	155.66**	5.08**	1373.33**	2144.62**	292.74**	16.85**	5.66**
T × E	16	367.44**	20.77**	3.93	0.47*	599.76**	0.18**	7.96**	1.86**	61.81**	2.58**	1147.41**	337.77**	128.96**	70.34**	3.10**
L × T × E	80	177.44**	10.64*	3.31	0.39**	229.75**	0.18**	8.74**	0.75**	23.85**	2.08**	967.24**	175.83**	45.82**	53.40**	5.95**
Pooled Error	318	18.21	7.91	3.20	0.23	90.22	0.04	2.32	0.26	3.02	0.28	125.22	60.92	13.97	2.52	0.74
Components of Genetic Variance																
σ^2gca		1.01**	4.16**	0.01	0.19**	130.62**	0.01**	4.32**	0.27**	9.19**	0.03**	148.34**	-7.55**	3.49**	-3.91**	3.42**
σ^2sca		45.56**	1.44**	-0.17	0.03**	50.07**	0.07**	4.20**	0.05**	12.99**	1.16**	-94.20**	5.47**	5.79**	597.40**	64.78**
σ^2gca/ σ^2sca		0.02	2.88	—	5.82	2.61	0.08	1.03	4.97	0.71	0.03	—	—	0.60	—	0.05

*, ** significant at P ≤ 0.05 and P ≤ 0.01 levels of probability, respectively.

Where,

GY = Grain yield per plant (g)
DF = Days to 50% flowering
DM = Days to maturity
NMS = Nodes on main stem
PH = Plant height (cm)
ETP = Effective tillers per plant
EL = Earhead length (cm)
EG = Earhead girth (cm)
EW = Dry earhead weight (g)
TW = Test weight (g)
DFW = Dry fodder weight (g)
PI = Panicle index (%)
HI = Harvest index (%)
FE = Fe content (mgkg^{-1})
ZN = Zn content (mgkg^{-1})

Suryawanshi *et al*. (2021), Patil *et al*. (2021), Athoni *et al*. (2022a), Surendhar *et al*. (2023) and Ingle *et al*. (2023) for test weight; Mungra *et al*. (2015), Krishnan *et al*. (2017), Saini *et al*. (2018) and Patil *et al*. (2021) for harvest index; Gami *et al*. (2021), Barathi and Reddy (2022), Tribhuvan *et al*. (2023) and Ingle *et al*. (2023) for Zn content. Meanwhile, for nodes on the main stem, the result contradicted the findings obtained by Mungra *et al*. (2015) and Gami *et al*. (2021).

General Combining Ability effects

The estimates of general combining ability effects on a pooled basis for various characters (Table 3) revealed that the parents JMSA 20172, ICMA 98222, ICMA 98444, J-2562, J-2563 and J-2582 were good general combiners for grain yield per plant because these parents recorded significant and positive general combining ability effects in pooled over environments. Specifically, CMS lines JMSA 20172 displayed proficiency in grain yield per plant, nodes on the main stem, plant height, earhead length, dry earhead weight, test weight and dry fodder weight; ICMA 98222 for grain yield per plant, days to 50% flowering, earhead girth and harvest index; while ICMA 98444 good GCA for grain yield per plant, days to 50% flowering, earhead girth, test weight, harvest index and Fe content.

Among the testers, J-2562 demonstrated good general combining ability for grain yield per plant, plant height, earhead length, earhead girth, dry earhead weight, test weight and dry fodder weight; J-2563 for grain yield per plant, effective tillers per plant, earhead length, earhead girth, dry earhead weight, dry fodder weight and Fe content; while J-2582 identified as good general combiner for grain yield per plant, nodes on the main stem, plant height, earhead length, earhead girth, dry earhead weight, test weight and dry fodder weight.

Lines ICMA 04999, ICMA 98222 and ICMA 98444 and testers J-2372, J-2405 and J-2532 were identified as good general combiners for days to 50% flowering. ICMA 11222 and JMSA 20172 lines and a tester J-2582 were identified as good general combiners for nodes on the main stem. Meanwhile, ICMA 11222, JMSA 20172, J-2496, J-2562 and J-2582

Table 3 : Estimates of general combining ability (GCA) effects for different characters based on pooled over environments.

S. no.	Parents	GY	DF	DM	NMS	PH	ETP	EL	EG	EW	TW	DFW	PI	HI	FE	ZN
LINES																
1	**ICMA 04999**	-1.18*	-1.94**	-0.06	-0.51**	-11.04**	0.17**	-0.31	-0.84**	-2.49**	-0.69**	-5.39**	3.84**	1.82**	3.07**	2.53**
2	**ICMA 11222**	-1.56**	2.76**	0.30	0.58**	17.81**	0.04	1.50**	0.16**	4.08**	0.22**	19.94**	2.81**	-3.93**	7.60**	-0.59**
3	**JMSA 20172**	2.70**	3.67**	-0.27	0.75**	16.15**	-0.11**	3.37**	-0.27**	3.59**	0.36**	10.83**	0.33	-2.14**	-8.33**	-3.59**
4	**ICMA 98222**	1.41**	-2.80**	0.09	-0.51**	-14.69**	-0.16**	-3.61**	0.40**	0.11	-0.05	-12.20**	-0.88	2.97**	-3.81**	0.07
5	**ICMA 98444**	2.89**	-1.27**	-0.01	-0.16**	0.30	0.02	0.10	0.47**	-0.83**	0.27**	-4.15**	-3.03**	1.38**	2.95**	-1.66**
6	**ICMA 99222**	-4.27**	-0.42	-0.06	-0.16**	-8.53**	0.03	-1.05**	0.09	-4.45**	-0.10	-9.03**	-3.08**	-0.10	-1.48**	3.23**
TESTERS																
1	**J-2372**	-4.21**	-2.66**	-0.40	-0.06	-7.20**	-0.05	-1.42**	0.03	-1.66**	-0.47**	-0.41	-7.11**	-2.58**	-3.89**	1.84**
2	**J-2405**	-0.12	-1.18**	0.30	0.06	-3.01*	0.14**	-0.30	0.13	0.50*	-0.12	-2.43	-3.96**	-0.57	0.34	-1.73**
3	**J-2496**	-4.54**	0.19	-0.40	0.00	2.72*	-0.02	0.55**	0.73**	0.23	0.47**	-4.18**	-1.51	-0.82	2.85**	3.31**
4	**J-2500**	0.06	0.06	0.10	-0.23**	-6.08**	-0.06*	-2.23**	-0.60**	-2.47**	-0.43**	-16.54**	3.96**	4.47**	3.11**	-4.59**
5	**J-2532**	-2.50**	-1.27**	-0.29	-0.39**	-6.88**	0.15**	-0.72**	-1.08**	-5.69**	-0.30**	-18.66**	3.70**	4.11**	-1.57**	-0.09
6	**J-2562**	5.63**	-0.01	0.49*	0.07	4.37**	-0.03	2.79**	0.93**	3.96**	0.42**	14.78**	-0.43	-0.76	-1.56**	-1.39**
7	**J-2563**	3.38**	1.60**	0.10	0.01	1.73	0.11**	0.50*	0.20**	1.73**	0.08	4.78**	1.10	-0.25	0.80**	-0.02
8	**J-2582**	3.03**	2.14**	0.15	0.51**	16.21**	-0.12**	2.71**	0.24**	5.37**	0.25**	21.69**	-0.34	-3.22**	-4.43**	-0.17
9	**J-2608**	-0.72	1.12**	-0.03	0.03	-1.85	-0.12**	-1.88**	-0.58**	-1.97**	0.10	0.96	4.57**	-0.39	4.35**	2.84**

GY = Grain yield per plant (g)
DF = Days to 50% flowering
DM = Days to maturity
NMS = Nodes on main stem
PH = Plant height (cm)
ETP = Effective tillers per plant
EL = Earhead length (cm)
EG = Earhead girth (cm)
EW = Dry earhead weight (g)
TW = Test weight (g)
DFW = Dry fodder weight (g)
PI = Panicle index (%)
HI = Harvest index (%)
FE = Fe content (mgkg^{-1})
ZN = Zn content (mgkg^{-1})

for plant height were identified as good combiners.

ICMA 04999, J-2405, J-2532 and J-2563 exhibited notable performance as good general combiners for effective tillers per plant. ICMA 11222, JMSA 20172, J-2496, J-2562, J-2563 and J-2582 were good general combiners for earhead length; ICMA 11222, ICMA 98222, ICMA 98444, J-2496, J-2562, J-2563 and J-2582 for earhead girth and ICMA 11222, JMSA 20172, J-2405, J-2562, J-2563 and J-2582 were identified as good general combiners for dry earhead weight.

ICMA 11222, JMSA 20172, ICMA 98444, J-2496, J-2562 and J-2582 emerged as good general combiners for test weight in the conducted analysis. Similarly, ICMA 11222, JMSA 20172, J-2562, J-2563 and J-2582 for dry fodder weight; ICMA 04999, ICMA 11222, J-2500, J-2532 and J-2608 for panicle index and ICMA 04999, ICMA 98222, ICMA 98444, J-2500 and J-2532 demonstrated effectiveness as good general combiners for harvest index.

Concerning micronutrients, ICMA 04999, ICMA 11222, ICMA 98444, J-2496, J-2500, J-2563 and J-2608 were identified as good combiners for Fe content and ICMA 04999, ICMA 99222, J-2372, J-2496 and J-2608 for Zn content.

Specific Combining Ability effects

The estimates of SCA effects revealed that none of the hybrids was consistently superior for all the studied

Table 4 : Summary of best performing parents, best general combiners and best hybrids along with their SCA effects pooled over environment for various traits in pearl millet.

S. no.	Trait	Best performing Parent	Best General Combiner	Best performing Hybrid	SCA effect
1.	Grain yield per plant (g)	ICMA 11222	J-2562	JMSA 20172 x J-2563	9.13**
		J-2500	J-2563	ICMA 98444 x J-2582	8.07**
		ICMA 98222	J-2582	JMSA 20172 x J-2562	5.64**
2.	Days to 50% flowering	ICMA 11222	ICMA 98222	ICMA 98222 x J-2372	-0.22
		J-2532	J-2372	ICMA 04999 x J-2372	-0.53
		J-2372	ICMA 04999	ICMA 98222 x J-2532	-1.05
3.	Days to maturity	J-2532	J-2372	ICMA 04999 x J-2372	-0.61
		J-2562	J-2496	ICMA 04999 x J-2496	-0.50
		J-2500	J-2532	ICMA 99222 x J-2372	-0.50
4.	Nodes on main stem	J-2582	JMSA 20172	ICMA 11222 x J-2582	0.11
		J-2405	ICMA 11222	JMSA 20172 x J-2563	0.33*
		J-2562	J-2582	JMSA 20172 x J-2562	0.21
5.	Plant height (cm)	J-2582	ICMA 11222	ICMA 11222 x J-2582	3.29
		J-2405	J-2582	JMSA 20172 x J-2582	-0.14
		ICMA 11222	JMSA 20172	JMSA 20172 x J-2562	5.87
6.	Effective tillers per plant	J-2532	ICMA 04999	ICMA 11222 x J-2563	0.64**
		JMSA 20172	J-2532	ICMA 04999 x J-2405	0.19**
		J-2372	J-2405	ICMA 99222 x J-2532	0.33**
7.	Earhead length (cm)	JMSA 20172	JMSA 20172	JMSA 20172 x J-2562	1.94**
		J-2405	J-2562	ICMA 98444 x J-2562	3.77**
		J-2562	J-2582	JMSA 20172 x J-2496	1.16*
8.	Earhead girth (cm)	ICMA 98222	J-2562	ICMA 98444 x J-2562	0.51**
		J-2563	J-2496	ICMA 98222 x J-2582	0.84**
		J-2562	ICMA 98444	ICMA 98222 x J-2496	0.17
9.	Dry earhead weight (g)	J-2562	J-2582	ICMA 98444 x J-2582	5.17**
		ICMA 11222	ICMA 11222	JMSA 20172 x J-2562	1.23*
		J-2500	J-2562	ICMA 11222 x J-2562	0.63
10.	Test weight (g)	J-2562	J-2496	JMSA 20172 x J-2562	0.74**
		ICMA 99222	J-2562	JMSA 20172 x J-2563	1.07**
		J-2563	JMSA 20172	ICMA 98444 x J-2496	0.57**
11.	Dry fodder weight (g)	J-2562	J-2582	ICMA 11222 x J-2582	-3.14
		J-2563	ICMA 11222	ICMA 04999 x J-2582	18.59**
		J-2405	J-2562	ICMA 11222 x J-2562	0.11
12.	Panicle index (%)	J-2500	J-2608	ICMA 04999 x J-2608	5.95*
		ICMA 11222	J-2500	ICMA 11222 x J-2500	5.53*
		J-2608	ICMA 04999	ICMA 04999 x J-2532	4.31

Table 4 continued...

Table 4 continued...

13.	**Harvest index (%)**	J-2500	J-2500	ICMA 04999 x J-2532	4.23**
		ICMA 98222	J-2532	ICMA 98222 x J-2563	3.05*
		ICMA 98444	ICMA 98222	ICMA 04999 x J-2496	4.69**
14.	**Fe content (mgkg^{-1})**	J-2532	ICMA 11222	ICMA 11222 x J-2500	21.28**
		J-2496	J-2608	ICMA 11222 x J-2372	15.25**
		ICMA 98444	J-2500	ICMA 98222 x J-2532	22.21**
15.	**Zn content (mgkg^{-1})**	J-2532	J-2496	ICMA 99222 x J-2608	13.75**
		J-2496	ICMA 99222	ICMA 98222 x J-2496	3.37**
		ICMA 98444	J-2608	ICMA 99222 x J-2372	1.56**

*, ** significant at P ≤ 0.05 and P ≤ 0.01 levels of probability, respectively.

Table 5 : Promising hybrids for grain yield per plant based on SCA effects along with GCA effects of parent involved and component traits with desirable SCA effects over environments in pearl millet.

S. no.	The best specific combiner hybrids	SCA effects	GCA effect of parents		Desirable SCA effects for component traits
			Lines	Tester	
1.	ICMA 11222 x J-2500	10.01** (G)	-1.56** (P)	0.06 (A)	EW, TW, PI, HI, FE and ZN
2.	JMSA 20172 x J-2563	9.13** (G)	2.70** (G)	3.38** (G)	NMS, EW, TW, HI and ZN
3.	ICMA 99222 x J-2608	9.11** (G)	-4.27** (P)	-0.72 (A)	PH, EW, DFW, FE and ZN
4.	ICMA 98444 x J-2582	8.07** (G)	2.89** (G)	3.03** (G)	NMS, PH, EW and DFW
5.	ICMA 04999 x J-2582	7.46** (G)	-1.18* (P)	3.03** (G)	EL, EW, DFW, FE and ZN

*, ** significant at P ≤ 0.05 and P ≤ 0.01 levels of probability, respectively.
Where, **G** = Good parent having significant GCA effects in desired direction
A = Average parent having either positive or negative but non-significant GCA effects
P = Poor parent having significant GCA effects in undesired direction

GY	= Grain yield per plant (g)	**ETP**	= Effective tillers per plant	**DFW**	= Dry fodder weight (g)
DF	= Days to 50% flowering	**EL**	= Earhead length (cm)	**PI**	= Panicle index (%)
DM	= Days to maturity	**EG**	= Earhead girth (cm)	**HI**	= Harvest index (%)
NMS	= Nodes on main stem	**EW**	= Dry earhead weight (g)	**FE**	= Fe content (mgkg^{-1})
PH	= Plant height (cm)	**TW**	= Test weight (g)	**ZN**	= Zn content (mgkg^{-1})

traits. Out of 54 hybrids studied, 17 exhibited significant positive SCA effects for grain yield per plant on a pooled basis.

The detailed analysis regarding best-performing parents, best general combiners and best hybrids, along with their SCA effects, pooled over the environment for various traits is presented in Table 4. The top five hybrids, namely ICMA 11222 x J-2500, JMSA 20172 x J-2563, ICMA 99222 x J-2608, ICMA 98444 x J-2582 and ICMA 04999 x J-2582 (Table 5), were identified based on their significant positive specific combining ability (SCA) effects for grain yield per plant. Consequently, these hybrids, characterized by elevated SCA effects for grain yield per plant were linked with significant and desirable SCA effects for yield-contributing traits and certain quality traits.

Among these hybrids, the best three specific combiner hybrids for grain yield per plant pooled over environments were ICMA 11222 x J-2500, JMSA 20172 x J-2563 and ICMA 99222 x J-2608. Among these, hybrid ICMA 11222 x J-2500 was also found good specific combiner for dry earhead weight, test weight panicle index, harvest index, Fe content and Zn content; JMSA 20172 x J-2563 for nodes on main stem, dry earhead weight, test weight, harvest index and Zn content and ICMA 99222 x J-2608 for plant height, dry earhead weight, dry fodder weight, Fe content and Zn content.

Conclusion

The CMS lines JMSA 20172, ICMA 98222, ICMA 98444 and male parents/testers J-2562, J-2563 and J-2582 were good general combiners for grain yield per plant and the majority of its attributes were pooled over the environments. Hence, these parental lines hold significant potential for the concurrent enhancement of favorable agronomic and morphological traits, in addition to facilitating heterosis breeding. Among the crosses, the top three specific combiner hybrids identified for grain yield per plant were ICMA 11222 x J-2500, JMSA 20172 x J-2563 and ICMA 99222 x J-2608. These combinations demonstrated significant and favorable specific combining ability (SCA) effects for grain yield and desirable effects for some other component characters.

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