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Unravelling the Interplay of General Combining Ability and Per Se Performance for Grain Yield and Nutritional Quality Traits in Pearl Millet (*Pennisetum glaucum* L.)

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ABSTRACT: Selecting superior parental lines is essential for enhancing yield and quality traits in pearl millet hybrid breeding. This study assessed the general combining ability (GCA) of parental lines and their relationship with per se performance, focusing on grain yield and quality. Two sets of 72 test crosses involved 24 parental lines and 12 testers, evaluated across multiple locations. Statistical analyses, including Analysis of variance, combining ability, and correlation assessments, identified good general combiners. R-L1, R-L10, B-L7, B-L8, and B-L1 displayed the highest GCA effects for grain yield. The positive correlation between per se performance and GCA effects suggests that high GCA lines have the potential to perform well in different yield categories, making their selection in high-yield lines a more rewarding choice for seed production. A significant positive correlation between GCA effects and hybrid performance underlines the predictive power of GCA in enhancing breeding efficiency and reducing resource consumption in developing high-yielding single-cross hybrids in pearl millet.

Keywords: General combining ability, *Per se* performance, Correlation, Analysis of Variance, Line × tester.

INTRODUCTION

The conceptualization of heterosis and exploitation of hybrids has stimulated commercial pearl millet production. The hybrid development has become a focused approach of all the pearl millet breeders across the country due to the adaptive and yield advantage of hybrids. Hybrids offer tremendous opportunities to boost the yield potential of pearl millet; being a highly cross-pollinated crop, it offers huge scope for exploiting hybrid vigour. In India, hybrids occupy about 5.0 M ha of the area under pearl millet; the rest is under open-pollinated varieties (OPVs) or landraces (Sathyavathi, 2017). Since the 1960s, Indian pearl millet breeding programs have harnessed heterosis by developing hybrid cultivars, with productivity increases of 3 per cent per annum during 1990 to 2017 (Yadav *et al*., 2019).

Traditionally, breeders create numerous crosses among lines selected based on pedigree information. However, pedigree data alone may not provide enough information for breeders to make informed decisions about which materials to use in crosses. Developing hybrids involves obtaining homozygous lines from diverse source populations and gene pools, evaluating their performance in various cross combinations, and assessing their individual performance (Bauman, 1981 and Hallauer, 1990). Assessing the relative performance of inbred lines through test crosses with appropriate testers has proven to be a valuable strategy for selecting inbred lines with favorable combining abilities and superior performance in hybrids. The efficacy of using per se performance and combining ability effects as indicators for predicting hybrid per se performance has been noted in prior research conducted by Schrag *et al.* (2009), Pucher *et al.* (2016), Singh *et al.* (2018), Sattler *et al.* (2019) and Patil and Gupta (2021). Therefore, the objective of the present study was to identify promising general combiners and understand the relationship between per se performance and general combining ability. This understanding can contribute to the formulation of breeding strategies.

MATERIAL AND METHODS

A. Development of testcross hybrids and their evaluation

A set of 24 new hybrid parents, comprising 12 seed parents (B-lines: B-L1 to B-L12) and 12 restorer parents (R-lines: R-L1 to R-L12) with diverse pedigrees, were used as lines. Additionally, a set of 12 inbreeds, including six seed parents (B-T1 to B-T6) and six restorer parents (R-T1 to R-T6), were used as testers. The present study focused on B × R hybrids, although A × R hybrids must be developed for cultivation.

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These two sets of line × tester crosses (Set-1 and Set-2), along with their parents and commercial checks, were evaluated at four different locations during the rainy season of 2020 in India, namely Jaipur, Alwar, Aurangabad, and Pachora. In general, hybrids and parental genotypes were randomized separately and evaluated in adjacent blocks to avoid the suppressive effect of hybrids over parents. Hybrid entries were evaluated in an Alpha lattice design with two replications, whereas parental genotypes were evaluated in a Randomized Completed Block Design (RCBD) with two replications. Standard agronomic management practices were followed at all locations for optimal crop growth.

B. Observations recorded

In each plot and replication, five plants were randomly tagged and used for recording observations on traits such as Plant height (PH) (cm), Number of productive tillers per plant (NPT), Panicle length (PL) (cm), and Panicle girth (PG) (cm). Simultaneously, observations on Days to 50% flowering (DFF) (days), Days to maturity (DM) (days), 1000-grain weight (TGW) (g), Grain Iron (Fe) and Zinc (Zn) density (mg kg^{-1}), and Grain yield (GY) (kg ha^{-1}) were recorded on a plot basis.

Grain yield (kg ha^{-1}): All panicles from each plot were harvested at maturity. These panicles were sundried for 10 to 15 days and then threshed to obtain grain yield. After threshing, the grain from all plants in a plot was weighed. Plot yield was converted into kg ha^{-1} using the following formula

$$\text{Yield (Kg ha}^{-1}) = \frac{\text{Plot yield (kg)} \ \times \ 10000}{\text{Plot size (m}^2)}$$

C. Statistical analyses

A combined analysis of variance was conducted using PROC MIXED (SAS v9.4, SAS Institute Inc. 2017), with location, genotypes, and replication considered as fixed factors, and block as a random factor. To pool the data across locations and ensure homogeneous error variance, individual location variances were estimated and modeled using the residual maximum likelihood (REML) procedure.

Combining ability analysis is a important tool for assessing combining ability effects and helps in the selection of desirable parents for creating crosses, as well as crosses for exploiting heterosis. Line × tester analysis provides insights into the GCA effects of parents. This information was utilized to identify excellent general combiners from new germplasm for achieving high grain productivity and associated traits. The line × tester analysis, following Kempthorne's (1957) procedure, was employed to estimate both general and specific combining ability effects. Pearson correlation coefficients were calculated to assess the linear relationships between pairs of variables.

RESULTS AND DISCUSSION

A. Analysis of variance (ANOVA)

The analysis of variance for combining ability related to grain yield and its component traits is presented in Table 1. The ANOVA results showed highly significant variance ($p<0.05$) attributed to environments (locations) for both sets of hybrids, indicating that the materials were evaluated across diverse environmental conditions. The analysis of variance for hybrids indicated that genotypic variation due to hybrids was highly significant for all the studied traits. This suggests the presence of ample genetic variation, allowing for significant progress through selection for improvements in most measured traits. The variance attributable to the general combining ability (σ^2GCA) of lines was significant for all traits. Similarly, the variance due to the general combining ability (σ^2GCA) of testers was also significant for most traits, suggesting substantial differences among parental genotypes in their combining ability. The significant variances due to lines and testers for various traits in hybrid datasets revealed satisfactory variability among lines and testers, thereby facilitating further analysis of combining ability.

Identification of good general combiners for high grain productivity and its linked traits in pearl millet

The selection of parents to enhance yield and other desirable traits is an important step in the breeding program. Evaluating the performance of lines and testers across various cross combinations helps identify them as good or poor combiners. Therefore, the ability of lines to produce superior offspring was assessed based on their General GCA effects. GCA effects of parental genotypes were estimated for yield and its component traits, and the details of GCA effects for new hybrid parental lines, evaluated across locations, are presented in Table 2. The top-performing general combiners from the new germplasm, exhibiting the highest GCA for grain yield and its component traits, are listed in Table 3.

The GCA effects for grain yield (kg ha^{-1}) ranged from -355.19** (R-L4) to 525.72** (R-L10) for new R-lines with two parents having positively significant GCA effects; from -771.85** (B-L11) to 642.46** (B-L1) for new B –lines with three parents having positively significant *GCA* effects. Overall, genotypes differed widely for their GCA effects in both directions. Eleven genotypes from new germplasm exhibiting significant positive GCA effects were considered as good general combiners for grain yield. Previous studies in pearl millet by Solanki *et al*. (2017), Rai *et al*. (2017), Stattler *et al*. (2019), Warrier *et al*. (2020) were also reported good general combiners for grain yield. Parents showing a significantly positive GCA for grain yield could be employed in the creation of superior hybrids or the creation of a base population for selection.

The GCA effects for grain Fe content varied from -10.97** (R-L10) to 10.50** (R-L2) for new R-lines, with four parents exhibiting positively significant GCA effects. For new B-lines, the GCA effects ranged from -11.26** (B-L1) to 13.80** (B-L4), and four parents displayed positively significant GCA effects. This study observed both positive and negative significant GCA effects, aligning with findings by Rai *et al*. (2012), Govindaraj *et al*. (2013), and Kanatti *et al*. (2014). This suggests that gene combinations in different lines are not similar.

In the current study, there was a substantial variation among the lines in terms of their GCA effects for all the traits under investigation (Table 2). These variations in GCA effects can be attributed to differences in the frequencies of genes transmitted to the progeny with additive effects (Falconer and Mackay 1996). The discrepancies in gene frequencies among the genotypes indicate significant genotypic differences, thus providing justification for their selection in the present study.

Parental lines R-L2, R-L7, R-L1, R-L6, and B-L7, B-L1, B-L2, B-L6, B-L9 exhibit highly significant General GCA effects for the majority of the traits. Consequently, these parental lines can serve as good combiners for developing hybrids. Inter-mating these parents (BxB and RxR) offers the opportunity to establish a base population, yielding new recombinants that can be further utilized for deriving inbred lines with favorable combining abilities.

Association between *per se* performance of parents and their GCA effects for grain yield and its component traits

Association of per se performance of new B and R lines with their GCA effects for grain yield and its component traits is provided in Table 4. A significant and high positive correlation was observed between GCA effects and *per se* performance of the parental genotypes for the traits PG, TWG, Fe, and Zn in both testcrosses of B and R lines. The significant-high positive association indicated that the probability of deriving good combiners is high in high *per se* backgrounds. A significant positive correlation between combining ability and parental *per se* performance was also reported in other crops, like sorghum (Premalatha *et al*., 2006, Rajendrakumar, 2015; Akata *et al*., 2017). Other traits like DFF, DM, PL, PH and NPT also had a positive and high correlation of GCA effects with parental mean values in most of the cases except for PL of new R lines, PH of new B lines where the association was negative but non-significant. The weak correlation observed between the per se performance of the inbred line and its GCA effects on such traits may be attributed to the involvement of distinct gene sets governing these two aspects, as suggested by Turner (1953) and Ai-Zhi *et al*. (2012).

The positive but non-significant correlation between GCA and the per se performance of parents in terms of grain yield suggests that high general combiners are equally likely to occur in any of the yield groups (or even more likely to occur in lines with high grain yield *per se* than in any other yield group). Given the economic considerations of seed production and the increased likelihood of obtaining a high-yielding hybrid, it is advisable for seed parents to possess both high yield per se and high GCA. Rai (1999) also reported similar findings in pearl millet. This suggests that if high GCA lines are equally probable across a wide range of yield categories, selecting them within high-yielding lines becomes a more remunerative approach for seed production. On the other hand, if high GCA lines are more likely to occur in high-yielding lines, the initial selection based on line yield (per se) is a simpler and more cost-effective evaluation compared to GCA evaluation, as indicated by Rai *et al*. (2006). Then one can later evaluate for combining ability (both GCA and SCA) among the selected lines. This will reduce the number of crosses to be carried out on field evaluation through effective selection of parents with good combining ability. Therefore, improving the parental GCA and *per se* performance for yield and yield components, together with desired grain quality traits, are the keys to breeding hybrid parents and, therefore, hybrids.

Association between general combining ability effects of parental lines and hybrid *par se* performance for grain yield and its component traits

Table 5 presents the correlation between the General Combining Ability (GCA) effects of parents and the *per se* performance of hybrids for grain yield and its component traits. The relatively strong correlation indicates that the combined GCA effects of parents retain a higher level of predictability for the per se performance of hybrids. This implies that the per se performance of hybrids can be effectively predicted based on the GCA of their parents, which is influenced by additive effect genes (Falconer and Mackay 1996). Utilizing parental GCA effects for predicting hybrid performance proves to be a resource-efficient strategy, allowing the evaluation of only a select few hybrids that are anticipated to be the most promising.

This study demonstrates that the correlation between the *per se* performance of hybrids and the GCA effects of parents serves as a valuable tool for predicting the per se performance of hybrids across all investigated traits, including grain yield and nutritional quality traits. By selecting superior inbreds with strong GCA effects for grain yield and its component traits, the production of high-yielding single-cross hybrids becomes more achievable. Consequently, the GCA of parents can be effectively utilized as a predictive tool for developing hybrids with superior per se performance, leading to a reduction in the use of input resources and an enhancement of breeding efficiency. The efficacy of parental GCA effects in predicting hybrid per se performance has also been noted in previous studies by Schrag *et al*. (2009), Pucher *et al*. (2016), Singh *et al*. (2018), Sattler *et al*. (2019), and Patil *et al*. (2021).

Table 1: Combined analysis of variance for combining ability.

Source of variation	df	DFF	PH	PL	PG	DM	GY	TGW	Fe	Zn	df	NPT
Set-1												
Environment	3	62.35***	99***	21.41***	41.82***	361.06***	17.39***	134.13***	183.78***	182.11***	2	1031.24***
Replication (Loc.)	4	4.06**	4.14**	7.62**	2.86*	4.26**	10**	1.74	3.47	2.42	3	7.55**
Hybrids	71	12.89***	22.68***	9.19***	11.69***	11.95***	2.46***	5.95***	19.24***	11.23***	71	1.3
Line (GCA)	11	18.45***	11.12***	12.98***	10.57***	16.87***	2.45*	6.6**	6.52***	7.83***	11	2.08**
Tester (GCA)	5	46.85***	36.93***	59.92***	135.39***	39.21***	2.98*	4.85*	25.31***	21.47***	5	5.58**
Line × Tester (SCA)	55	1.88**	4.41***	1.31	0.96	1.97**	1.76**	5.93***	5.12***	3.08***	55	0.69
ENV × Hybrids	213	2.05***	3.86***	1.02	1.11	2.58***	1.99***	1.78**	3.87***	2.75***	142	1.32
ENV × LINE (GCA)	33	3.64***	0.92	0.96	1.05	7.26***	2.22**	1.35	2.38**	2**	22	0.51
ENV × TESTER (GCA)	15	6***	4.05***	1.79	1.55	5.94***	2.87**	2.83**	3.35***	3.07**	10	1.26
ENV × LINE × TESTER (SCA)	165	1.13	2.87***	0.97	1.06	1.09	1.47*	1.51**	2.62***	1.99**	110	1.09
Set-2												
Environment	3	104.28***	210.86***	27.13***	106.63***	301.15***	9.29**	280.03***	74.6***	193.57***	2	847.38***
Replication (Loc.)	4	5.51**	2.3	1.63	1.57	4.78**	3.51*	1.59	0.19	2.4	3	3.32*
Hybrids	71	12.98***	31.34***	14.11***	10.91***	12.1***	3.07***	5.23***	14.57***	5.06***	71	0.97
Line (GCA)	11	16.67***	23.47***	12.11***	10.94***	15.05***	4.91***	9.74***	12.4***	8.73***	11	3.38**
Tester (GCA)	5	17.44***	17.81***	31.48***	40.96***	14.05***	3.57**	7.61***	3.2*	13.7***	5	2.47
Line × Tester (SCA)	55	2.77***	5.28***	2.86***	2.01**	2.77***	1.75**	1.88**	5.01***	1.67**	55	0.65
ENV × Hybrids	213	2.52***	3.86***	1.28	0.94	2.44***	1.59**	1.69**	3.31***	1.48*	142	1.12
ENV × LINE (GCA)	33	2.84***	2.26**	0.96	1.21	3.73***	1.5	1.7*	1.18	0.99	22	1.16
ENV × TESTER (GCA)	15	5.1***	2.95**	1.62	1.87*	5.4***	2.15**	3.1**	2.13*	2.4**	10	3.51**
ENV × LINE × TESTER (SCA)	165	1.6**	2.88***	1.22	0.86	1.35*	1.33*	1.34*	2.91***	1.31	110	0.93

*, **, *** F-value significant at 0.05, 0.01, < 0.001 levels of probability, respectively

Note: DFF- Days to 50% Flowering, PH- Plant height (cm), NPT- Number of productive tillers plant^{-1}, PL- Panicle length (cm), PG- Panicle girth (cm), DM- Days to maturity, GY- Grain Yield (kg ha^{-1}), TGW- 1000 grain weight (g), Fe- Grain Iron content (mg kg^{-1}) and Zn- Grain Zinc content (mg kg^{-1})

Table 2: General combining ability (GCA) effects of new B and new R lines for grain yield and its component traits across locations.

Genotype	DFF	PH	NPT	PL	PG	DM	GY	TGW	Fe	Zn
New R lines										
R-L1	0.34	-10.82**	-0.05	2.77**	0.09*	-0.03	410.87**	1.48**	-1.3	-1.06
R-L2	1.13**	7.94**	-0.03	-1.06**	0.14**	0.68**	59.62	0.84**	10.50**	6.17**
R-L3	-1.37**	0.86	-0.03	-0.06	0.07	-1.01**	-268.15*	0.28	-0.03	-0.74
R-L4	-1.17**	-3.00*	0.04	-0.61	0.07	-0.89**	-355.19**	-0.24	-7.19**	-6.61**
R-L5	-1.00**	2.60*	0.14**	-2.17**	-0.35**	-0.67**	147.67	-1.49**	-2.50**	3.37**
R-L6	4.20**	14.27**	-0.02	-0.04	0.02	3.49**	-151.67	-0.3	6.49**	-2.51**
R-L7	1.61**	7.38**	-0.02	2.02**	0.11**	1.91**	132.77	0	0.01	1.63*
R-L8	-2.17**	-14.86**	-0.03	-2.16**	-0.02	-1.97**	-136.03	-0.96**	2.05*	0.09
R-L9	-0.17	5.90**	-0.03	-0.31	-0.13**	0.19	-35.97	-0.2	0.55	1.80**
R-L10	-0.05	10.38**	0.04	2.28**	-0.05	-0.04	525.72**	-0.49*	-10.97**	-6.24**
R-L11	-0.99**	-21.74**	-0.03	-1.05**	0.10*	-0.99**	-103.46	0.46*	0.03	1.06
R-L12	-0.35	1.09	0.02	0.39	-0.05	-0.67**	-226.20*	0.61**	2.38**	3.03**
New B lines										
B-L1	3.09**	40.00**	-0.04	5.83**	-0.21**	3.10**	642.46**	-1.21**	-11.26**	-4.07**
B-L2	0.59*	2.77	0	1.32**	0.26**	0.49*	66.71	0.35	-0.03	2.06**
B-L3	-0.76**	-10.14**	0.03	-0.16	-0.16**	-0.66**	-287.39**	-0.42*	-7.12**	-3.53**
B-L4	-2.93**	-7.31**	0.07*	-1.19**	-0.21**	-2.35**	-142.44	1.20**	13.80**	6.26**
B-L5	-0.51	-2.19	-0.02	0.27	0.02	-0.46	-49.26	-0.33	-3.81**	-1.08
B-L6	1.97**	2.62	-0.02	-0.71	0.20**	1.64**	139.54	0.4	9.85**	1.85*
B-L7	1.37**	-11.05**	-0.04	1.15**	0.25**	1.00**	246.00*	0.47*	5.31**	3.20**
B-L8	2.25**	27.32**	-0.02	-0.24	0.06	2.01**	401.67**	1.29**	0.11	-3.85**
B-L9	-3.37**	-24.47**	-0.01	-1.38**	0.14**	-2.69**	63.53	0.48*	8.00**	2.59**
B-L10	-0.47	-14.75**	-0.06*	-3.47**	0.06	-0.86**	-217.60*	-1.53**	-1.66	-1.47
B-L11	-1.04**	-4.56**	0.04	-2.61**	-0.23**	-0.92**	-771.85**	-0.97**	-9.87**	-0.84
B-L12	-0.2	1.76	0.09**	1.20**	-0.19**	-0.3	-91.39	0.27	-3.32**	-1.11

*, ** Significant at 0.05, and 0.01 levels of probability, respectively

Note: DFF- Days to 50% Flowering, PH- Plant height (cm), NPT- Number of productive tillers plant^{-1}, PL- Panicle length (cm), PG- Panicle girth (cm), DM- Days to maturity, GY- Grain Yield (kg ha^{-1}), TGW- 1000 grain weight (g), Fe- Grain Iron content (mg kg^{-1}) and Zn- Grain Zinc content (mg kg^{-1})

Table 3: List of good combiners from new germplasm having top most general combining ability effects (gca) for grain yield and its component traits.

Traits	DFF	PH	NPT	PL	PG	DM	GY	TGW	Fe	Zn
New R lines	R-L8 (-2.17**)	R-L5 (2.60*)	R-L5 (0.14**)	R-L7 (2.02**)	R-L1 (0.09*)	R-L2 (0.68**)	R-L1 (410.87**)	R-L11 (0.46*)	R-L8 (2.05*)	R-L7 (1.63*)
	R-L3 (-1.37**)	R-L9 (5.90**)		R-L10 (2.28**)	R-L11 (0.10*)	R-L7 (1.91**)	R-L10 (525.72**)	R-L12 (0.61**)	R-L12 (2.38**)	R-L9 (1.80**)
	R-L4 (-1.17**)	R-L7 (7.38**)		R-L1 (2.77**)	R-L7 (0.11**)	R-L6 (3.49**)		R-L2 (0.84**)	R-L6 (6.49**)	R-L12 (3.03**)
	R-L5 (-1.00**)	R-L2 (7.94**)			R-L2 (0.14**)			R-L1 (1.48**)	R-L2 (10.50**)	R-L5 (3.37**)
	R-L11 (-0.99**)	R-L10 (10.38**)								R-L2 (6.17**)
		R-L6 (14.27**)								
New B lines	B-L9 (-3.37**)	B-L8 (27.32**)	B-L4 (0.07*)	B-L7 (1.15**)	B-L9 (0.14**)	B-L9 (-2.69**)	B-L7 (246.00*)	B-L7 (0.47*)	B-L7 (5.31**)	B-L6 (1.85*)
	B-L4 (-2.93**)	B-L1 (40.00**)	B-L12 (0.09**)	B-L12 (1.20**)	B-L6 (0.20**)	B-L4 (-2.35**)	B-L8 (401.67**)	B-L9 (0.48*)	B-L9 (8.00**)	B-L2 (2.06**)
	B-L11 (-1.04**)			B-L2 (1.32**)	B-L7 (0.25**)	B-L11 (-0.92**)	B-L1 (642.46**)	B-L4 (1.20**)	B-L6 (9.85**)	B-L9 (2.59**)
	B-L3 (-0.76**)			B-L1 (5.83**)	B-L2 (0.26**)	B-L10 (-0.86**)		B-L8 (1.29**)	B-L4 (13.80**)	B-L7 (3.20**)
						B-L3 (-0.66**)				B-L4 (6.26**)

*, ** Significant at 0.05, 0.01 levels of probability, respectively
Numbers in parenthesis indicate the GCA effect values of the parental genotypes
Note: DFF- Days to 50% Flowering, PH- Plant height (cm), NPT- Number of productive tillers plant^{-1}, PL- Panicle length (cm), PG- Panicle girth (cm), DM- Days to maturity, GY- Grain Yield (kg ha^{-1}), TGW- 1000 grain weight (g), Fe- Grain Iron content (mg kg^{-1}) and Zn- Grain Zinc content (mg kg^{-1})

Table 4: Correlation between *per se* performance of parents and their GCA effects for Grain yield and its component traits.

	DFF	PH	NPT	PL	PG	DM	GY	TGW	Fe	Zn
R lines	0.548	0.809**	0.738**	-0.018	0.729**	0.549	0.465	0.794**	0.761**	0.886**
B lines	0.944**	-0.043	0.056	0.791**	0.807**	0.958**	0.322	0.807**	0.867**	0.894**

*, ** Significant at 0.05, 0.01 levels of probability, respectively
Note: DFF- Days to 50% Flowering, PH- Plant height (cm), NPT- Number of productive tillers plant^{-1}, PL- Panicle length (cm), PG- Panicle girth (cm), DM- Days to maturity, GY- Grain Yield (kg ha^{-1}), TGW- 1000 grain weight (g), Fe- Grain Iron content (mg kg^{-1}) and Zn- Grain Zinc content (mg kg^{-1})

Table 5: Correlation between the sum of GCA effects of parents and their hybrid *per se* for grain yield and its component traits.

Traits	DFF	PH	NPT	PL	PG	DM	GY	TGW	Fe	Zn
Set-1 (6 B Testers × 12 New R lines)	0.944**	0.920**	0.805**	0.943**	0.968**	0.932**	0.658**	0.830**	0.883**	0.865**
Set-2 (12 New B lines × 6 R Testers)	0.911**	0.925**	0.692**	0.919**	0.925**	0.903**	0.752**	0.849**	0.859**	0.869**

*, ** Significant at 0.05, and 0.01 levels of probability, respectively
Note: DFF- Days to 50% Flowering, PH- Plant height (cm), NPT- Number of productive tillers plant^{-1}, PL- Panicle length (cm), PG- Panicle girth (cm), DM- Days to maturity, GY- Grain Yield (kg ha^{-1}), TGW- 1000 grain weight (g), Fe- Grain Iron content (mg kg^{-1}) and Zn- Grain Zinc content (mg kg^{-1})

CONCLUSION

In conclusion, this study on the interplay of GCA and per se performance in pearl millet provides useful insights for the improvement of grain yield and nutritional quality traits in pearl millet hybrid breeding programs. The identification of good general combiners, such as R-L1, R-L10, B-L7, B-L8, and B-L1, based on their GCA effects for grain yield, underscores the significance of selecting superior parental lines. The positive no significant correlation observed between per se performance and GCA effects implies that high GCA lines have the potential to perform well across different yield categories, selecting them in high yielding backgrounds are promising candidates for seed production. The study emphasizes the predictive power of GCA, as evidenced by the significant positive correlation between sum of parental GCA effects and hybrid performance. This predictive capability of GCA can enhance breeding efficiency, allowing for the development of high-yielding single-cross hybrids in pearl millet while reducing resource consumption required for testing unnecessary crosses. Overall, the findings underscore the importance of considering both GCA and per se performance in the selection of parental lines for hybrid breeding strategies.

FUTURE SCOPE

The good general combiner parental lines identified can be utilized to develop superior hybrids. Further investigations can focus on specific combinations of these parents to optimize hybrid performance, considering not only grain yield but also other desirable traits such as nutritional quality and stress tolerance. The identified parents can be systematically inter-mated (B×B or R×R) to establish a base population. This base population can serve as a source for deriving new recombinants through controlled crosses. The goal would be to enhance genetic diversity and capture favorable traits from different parental lines. Developing predictive models that integrate GCA and per se performance data to predict the potential success of hybrid combinations. Such models can assist breeders in making informed decisions about which parental lines to prioritize, ultimately improving the efficiency of hybrid breeding programs.

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