International Journal of Environment and Climate Change

Volume 13, Issue 11, Page 993-1000, 2023; Article no.IJECC.107472
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Genetic Analysis of Pearl Millet [*Pennisetum glaucum* (L.) R. Br] Lines for Yield and Yield Contributing Traits

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2023/v13i113249

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/107472

Original Research Article

Received: 25/07/2023
Accepted: 30/09/2023
Published: 16/10/2023

ABSTRACT

This investigation was conducted to study combining ability along with inheritance of grain yield and its component traits in 36 hybrids of pearl millet which were generated through line × tester mating design using 12 male sterile lines and 3 restorers as parental material at IIMR, Hyderabad during *kharif,* 2022. These hybrids were evaluated in randomized block design with 3 replications during *kharif*, 2022 and summer, 2023 at IIMR, Hyderabad. In results, both GCA and SCA variances were found significant for majority of characters. The ratio of GCA and SCA variance indicated the predominance of non-additive gene action for all the characters studied except for panicle length and panicle width. GCA effects revealed that parents like 274A, 269A, 04999A and 260A (female) and 123R (male) were good general combiners for grain yield and some contributing characters. On the basis of SCA effects the crosses namely 252A × 124R, 843-22A × 124R, 843-22A × 132R,

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242A × 123R, 264A × 132R and 274A × 123R were identified as superior for grain yield and related traits over the seasons. Therefore, it is advised that these parents and hybrids be used in the creation of fruitful hybrids as well as for population growth.

Keywords: Hybrids; pearl millet; photosynthetic efficiency; C4 plant.

1. INTRODUCTION

"Pearl millet (*Pennisetum glaucum*) is indeed an important coarse grain millet that belongs to the family Poaceae. It is a diploid plant with a chromosome number of 2n=2x=14" [1] It is a hardy and drought- resistant cereal crop that has been cultivated for thousands of years. Pearl millet's origin can be traced back to Africa. It is also known as bajra, bulrush millet, cat tail millet etc. In Telugu it is known as 'sajjalu'. "Pearl millet is one of the important cereal crops with nutritious grains and lower water and energy footprints in addition to the capability of growing in some of the harshest and most marginal environments of the world. Pearl millet is a warm season crop grown in rainfall ranging from 150-700mm. It is cultivated on about 27 million ha with the majority of crop area reported in Asia (>10 million ha) and Africa (about 18 million ha) with a production of 36 million tons" [2].

"Being a C4 plant, it has high photosynthetic efficiency and dry matter production capability even under low input conditions. Due to its climate resilient nature pearl millet can grow not only in the harshest conditions including soils with low moisture, high pH, high salinity, low fertility and high Al3+ saturation, but also in regions prone to frequent drought with low rainfall (annual average rainfall <250 mm) and high temperature, where other cereals fail to survive and produce grain" [3,4].

"Being highly cross-pollinated in nature facilitated by protogynous flowering, and owing to the availability of CMS systems, heterosis breeding is the most viable option in pearl millet. The real breakthrough was made when the first and the most widely used cytoplasmic male sterile line Tift 23A was utilized in development of grain hybrids in India" [5]. Selection based on phenotypic performance alone does not predict the performance of hybrids for grain yield as the trait is governed by non-additive gene action. The choice of right type of parent is a crucial step for a plant breeder which requires extensive and detailed genetical studies of existing germplasm as well as newly evolved promising lines. To make use of the parental lines, their combining abilities need to be elucidated. This genetic information can be obtained by different mating designs including line x tester mating design. To exploit heterosis to the maximum extent in desirable direction, it is desirable to identify good combining parents as well as superior specific combinations. Since general combining ability (GCA) estimate the average performance of a line in crosses, it reflects the breeding value of the line. Combining ability studies, therefore, aid in rejection of poor genotypes. The present study was carried out to estimate the combining ability variances and effects in crosses along with study of various components of genetic variation and to suggest suitable breeding strategy for improvement of yield under various environments.

2. MATERIALS AND METHODS

The experimental material for present study consisted of twelve lines (04999A, 843-22A, 221A, 242A, 246A, 252A, 260A, 262A, 264A, 269A, 274A and 291A) and three testers (123R, 124R,132R) and single standard check (KSB). During *Kharif* 2022, 12 lines were crossed with 3 testers using L × T design and simultaneously 36 hybrids which were generated during summer 2022 by crossing same set of parental lines were evaluated along with 15 parents and check with 3 replications at Indian Institute of Millets Research, Rajendranagar, Hyderabad. In summer, 2023 another evaluation of 36 hybrids which were generated during Kharif 2022 was carried out along with 15 parents and a check with 3 replications at Indian Institute of Millets Research, Rajendranagar, Hyderabad. Each entry was sown in two rows of 3m length at a spacing of 45 cm between the rows and 15 cm between the plants. All recommended cultural practices were followed to raise good crop. The observations were recorded for seventeen morphological characters viz., days to 50 percent flowering,days to maturity,plant height (cm), effective tillers per plant,flag leaf length (cm),flag leaf width (cm),leaf length (cm),leaf width (cm), actual photosystem ii efficiency (ΦPSII), Max maximum photosystem II efficiency (F_v/F_m),panicle length (cm), panicle width (cm), fresh biomass (kg per plot), dry biomass (kg per plot), grain yield (kg per plot),harvest index (%) and1000 seed weight (g). The mean data were subjected to analyze combining ability as per the method suggested by Kempthorne [6].

3. RESULTS AND DISCUSSION

3.1 Combining Ability Analysis

The pooled analysis of variance for combining ability (Table 1) showed mean sum of squares due to environments was significant for all the traits except leaf length which indicated presence of significant variations among the material used for study. Mean sum of squares due to crosses were found significant for all the traits except for maximum photosystem II efficiency. Mean sum of squares due to line × tester was found significant for all the traits except for panicle length, panicle width and maximum photosystem II efficiency. Mean sum of squares due to crosses x environment were found significant for all the traits except panicle width and maximum photosystem II efficiency. Mean sum of squares due to lines were found significant for days to 50% flowering, panicle length and panicle width while the tester mean sum of squares were found significant for panicle width. Perusal of Table 2 indicated that the magnitude of variance due to GCA was lower as compared to magnitude of SCA for all the characters except for panicle length and panicle width across the seasons which indicated the preponderance of non additive components for all the characters over the seasons except for panicle length and panicle width while significant magnitude of variance due to both GCA and SCA indicated the importance of both additive and non-additive components in the inheritance of majority of the characters studied. The proportional contribution of lines, testers and their interaction to total percentage of variance over the seasons (Table 2) showed maximum contribution of lines to total variance for panicle length (68.04%) followed by panicle width (65.59%). The maximum contribution of tester to total variance was for panicle width (10.89%) and the line x tester interaction displayed maximum contribution to total variance for number of effective tillers per plant (79.30%) followed by test weight (69%) over the seasons. Similar results were also reported in pearl millet by Kumawat et al. [7], Jeeterwal et al. [8], Kumar et al. [9], Solanki et al. [10], Mungra et al. [11].

3.2 GCA and SCA Effects

“The GCA and SCA effects in this section are based on the data pooled over two seasons. The best performing parents (lines and testers) and cross combinations on the basis of GCA and SCA effects revealed that none of the parents was found good general combiner for all the characters across the seasons which suggested breeding for these characters would be effective when material is tested over a wide range of environments. The female line 274A proved to be good general combiner as it showed significant GCA effects for twelve characters namely days to 50 percent flowering, days to maturity, plant height, effective tillers per plant, flag leaf width, leaf length, leaf width, fresh biomass, dry biomass, grain yield, harvest index and 1000 seed weight. While 269A was good general combiner for days to maturity, plant height, panicle width, fresh biomass, dry biomass, grain yield and 1000 seed weight” Kumawat et al. [7]. The line 260A was good general combiner for flag leaf width, panicle length, panicle width, dry biomass, grain yield and harvest index. Line 04999A was good general combiner for days to 50 percent flowering, days to maturity and fresh biomass. Line 262A for plant height and 1000 seed weight while 291A for panicle length. The tester or male parent 123R was good general combiner for characters namely days to maturity, effective tillers per plant, fresh biomass, dry biomass, grain yield and 1000 seed weight while 132R for Panicle length. Krishnan et al*.,* [12], Ladumor et al., [13], Saini et al., [14] and Santosh et al., [15] also reported various lines and testers having good combining ability behaviour for yield and its attributing characters in pearl millet.

The top three crosses for various characters based on high SCA effects are shown in (Table 3). The cross combinations with significant and high (highest three) SCA effects for at least three or more characters were 252A x 124R for characters namely days to 50% flowering, plant height, effective tillers per plant, flag leaf width, leaf length, leaf width, fresh biomass, dry biomass, grain yield, harvest index and 1000 seed weight, 274A x 123R for effective tillers per plant, dry biomass, harvest index and 1000 seed weight. 843-22A x 132R for plant height, flag leaf width, fresh biomass, harvest index and 1000 seed weight. Singh and Sharma [16], Eldie et al*.,* [17], Siddique et al., [18], Gavali et al., [19] and Ladumor et al., [13] also reported some specific combiners for yield and its contributing characters in pearl millet.

The cross 252A x 124R proved as best specific combiner over the seasons for twelve characters

Table 1. ANOVA for combining ability for grain yield per plot and its component traits

Source of variation	df	Mean sum of squares																
		DFF	DM	PH	ETP	FLL	FLW	LL	LW	PL	PW	Act PS II	Max PS II	FB	DB	GY	HI	TW
Replications	2	0.199	1.190	54.976	0.256	70.938**	0.133	8.136	0.084	8.214	2.067**	0.000	0.001	0.056	0.004	0.009*	23.934	0.230
Environments (e)	1	502.170**	53.542**	21291.690**	23.334**	234.194**	5.242**	110.641	2.834**	590.00**	46.667**	0.066**	1.520**	2.400**	0.234**	0.161**	470.059**	19.065**
Crosses (c)	35	20.671**	42.325**	990.419**	1.610**	67.731**	1.269**	76.643**	0.409**	23.717**	0.308*	0.030**	0.005	1.257**	0.083**	0.056**	228.246**	10.680**
Line (l**)**	11	35.045*	47.035	1181.756	0.922	74.627	1.312	111.929	0.531	51.349***	0.643***	0.031	0.004	1.293	0.088	0.061	236.145	9.827
Tester (t)	2	13.644	17.810	101.772	0.760	24.436	0.206	3.252	0.019	30.638	0.588*	0.006	0.007	0.268	0.013	0.016	59.963	3.876
l × t	22	14.123**	42.199**	975.537**	2.032**	68.219**	1.343**	65.671**	0.383**	9.272	0.115	0.031**	0.005	1.330**	0.087**	0.058**	239.595**	11.725**
c × e	35	21.994**	36.932**	1120.525**	1.834**	70.036**	1.417**	75.598**	0.616**	11.779**	0.275	0.031**	0.005	1.041**	0.079**	0.049**	179.031**	9.684**
Error	200	5.216	1.648	147.937	0.203	10.998	0.160	30.152	0.140	6.674	0.197	0.000	0.007	0.048	0.004	0.003	43.796	0.261

** and ** indicate significant at 5 per cent and 1 per cent levels of significance, respectively*

Table 2. Estimates of combining ability variances, genetic components and proportional contribution of lines, testers and their interactions to total variance (%) for various traits

Particulars	DFF	DM	PH	ETP	FLL	FLW	LL	LW	PL	PW	Act PS II	Max PS II	FB	DB	GY	HI	TW
σ^2 gca	0.455	0.68	10.359	0.013	0.819	0.012	0.487	0.002	0.746	0.009	0	0	0.016	0.001	0.001	2.85	0.146
σ^2 sca	1.705	6.728	133.32	0.297	9.257	0.188	5.002	0.036	0.309	-0.012	0.005	0	0.212	0.014	0.009	36.63	1.904
σ^2 gca/ σ^2 sca	0.26	0.1	0.07	0.04	0.08	0.06	0.09	0.05	2.41	-0.75	0	0	0.07	0.07	0.11	0.07	0.07
σ^2 A	0.909	1.3595	20.7177	0.0262	1.638	0.0242	0.9747	0.0047	1.4921	0.0189	0.0008	0	0.0322	0.002	0.0016	5.6995	0.2911
σ^2 D	1.7053	6.7275	133.3203	0.2968	9.2572	0.1882	5.002	0.0357	0.3086	-0.0125	0.0052	-0.0001	0.2123	0.0137	0.0091	36.63	1.9039
σ^2 A/σ^2 D	0.533	0.2021	0.1554	0.0884	0.1769	0.1288	0.1949	0.1323	4.8359	-1.5184	0.1584	-0.1511	0.1516	0.1486	0.1709	0.1556	0.1529
lines (l)	53.28	34.92	37.5	17.99	34.62	32.51	45.89	40.85	68.04	65.59	32.85	26.69	32.3	33.4	33.78	32.51	28.91
testers (t)	3.77	2.4	0.58	2.69	2.06	0.92	0.24	0.25	7.38	10.89	1.2	8.82	1.21	0.86	1.62	1.5	2.07
l × t	42.94	62.66	61.91	79.3	63.31	66.56	53.85	58.88	24.57	23.51	65.94	64.48	66.47	65.72	64.59	65.98	69

Table 3. Best performing parents (lines and testers) and crosses on the basis of GCA and SCA effects for pooled over seasons

Characters	Parents		Crosses
	Lines	Testers	
Days to 50% flowering	1.274A 2.264A 3.04999A	-	1. 242A × 124R 2. 252A × 124R 3. 262A × 132R
Days to maturity	1.274A 2.04999A 3.252A 4.269A	123R	1. 246A × 123R 2. 260A × 124R 3. 252A × 123R
Plant height (cm)	1.274A 2.262A 3.269A	-	1. 252A × 124R 2. 843-22A × 132R 3. 04999A × 124R
Effective tillers per plant	1.274A	123R	1. 252A × 124R 2. 242A × 123R 3. 274A × 123R
Flag leaf length (cm)	1.221A 2.264A 3.274A	-	1. 246A × 124R 2. 252A × 132R 3. 843-22A × 123R
Flag leaf width (cm)	1.260A 2.274A	-	1. 843-22A × 132R 2. 252A × 124R 3. 269A × 124R
Leaf length (cm)	1.274A	-	1. 252A × 124R
Leaf width (cm)	1.274A	-	1. 252A × 124R
Panicle length (cm)	1.260A 2.291A	132R	1. 269A × 123R
Panicle width (cm)	1.260A 2.269A	132R	-
Actual PS II efficiency (ΦPSII)	1.221A 2.242A 3.264A 4.246A	-	1. 252A × 132R 2. 246A × 124R 3. 843-22A × 123R
Fresh biomass (kg/plot)	1.04999A 2.269A 3.274A	123R	1. 252A × 124R 2. 264A × 132R 3. 843-22A × 132R
Dry biomass (kg/plot)	1.260A 2.269A 3.274A	123R	1. 252A × 124R 2. 274A × 123R
Grain yield (kg/plot)	1.260A 2.269A 3.274A	123R	1. 252A × 124R 2. 843-22A × 124R 3. 242A × 123R
Harvest index (%)	1.260A 2.269A 3.274A	-	1. 252A × 124R 2. 843-22A × 132R 3. 274A × 123R
1000 seed weight (gm)	1.262A 2.269A 3.274A	123R	1. 252A × 124R 2. 843-22A × 132R 3. 274A × 123R

Table 4. Hybrids showing significant specific combining ability effects for grain yield along with per se performance (g) and their performance in other traits

S.no	Crosses	SCA effect	Yield	Traits showing significant SCA effects
1	04999A × 124R	0.061*	0.613	Days to maturity, Plant height, fresh biomass, dry biomass, harvest index and 1000 seed weight
2	843-22A × 132R	0.100**	0.590	Days to maturity, plant height, flag leaf width, fresh biomass, dry biomass, harvest index and 1000 seed weight.
3	242A × 123R	0.079**	0.547	Effective tillers per plant, flag leaf width, fresh biomass, dry biomass, harvest index and 1000 seed weight.
4	246A × 123R	0.113**	0.660	Days to maturity, plant height, flag leaf width, fresh biomass, dry biomass, harvest index and 1000 seed weight.
5	252A × 124R	0.146**	0.692	Days to 50% flowering, Days to maturity, plant height, effective tillers per plant, flag leaf width, leaf length, leaf width, fresh biomass, dry biomass, harvest index and 1000 seed weight
6	260A × 124R	0.106**	0.701	Days to maturity, effective tillers per plant, dry biomass and 1000 seed weight.
7	262A × 123R	0.065**	0.650	Flag leaf width, dry biomass and 1000 seed weight.
8	264A × 132R	0.097**	0.540	Days to maturity, effective tillers per plant, flag leaf width, fresh biomass, dry biomass, harvest index and 1000 seed weight.
9	269A × 124R	0.084**	0.685	Days to maturity, effective tillers per plant, flag leaf width, fresh biomass, dry biomass, harvest index and 1000 seed weight.
10	274A × 123R	0.073**	0.726	Days to maturity, effective tillers per plant, dry biomass, grain yield, harvest index and 1000 seed weight.

** and ** represents significant at 5% and 1% level of significance, respectively* like days to 50 percent flowering, days to maturity, plant height, effective tillers per plant, flag leaf width, leaf length, leaf width, fresh biomass, dry biomass, grain yield, harvest index and 1000 seed weight followed by 274A × 123R for eight characters like days to maturity, effective tillers per plant, dry biomass, grain yield, harvest index and 1000 seed weight.

Out of total 36 crosses analyzed, 10 crosses showed positive significant SCA effects for grain yield per plot over the seasons which are presented in (Table 4) along with per se performance and traits also showing significant SCA effects along with grain yield per plot. Out of which 252A × 124R, 242A × 123R and 843-22A × 124R were found to be best top three performers for grain yield per plot and some of the component characters. Gavali et al*.,* [19], Ladumor et al., [13] and Saini et al., [14] also reported some specific combiners for pearl millet on the basis of SCA effects.

4. CONCLUSION

The study concluded that the ratio of additive to dominant variance was less than unity for all features except panicle length and panicle breadth across seasons, indicating that non-additive gene action predominated in the inheritance of the majority of the characters. Hence, recurrent selection or mass selection may be adopted for population developmentto exploit additive gene action in the present material and heterosis breeding may be adopted to exploit non-additive gene action for improving yield in pearl millet. GCA effects revealed that parents namely 274A, 269A, 260A, 04999A (female parents) and 123R (male parent) were good general combiners for grain yield per plot and some other attributes and can be utilized for development of synthetic populations in pearl millet. Amongst the total 36 crosses evaluated, the six crosses namely 252A × 124R, 843-22A × 124R, 843-22A × 132R, 242A × 123R, 264A × 132R and 274A × 123R were identified as superior for grain yield and related traits over the seasons exhibited high per se performance. Thus, these parents can be used to develop hybrids which can be included in multi-locational testing programme to identify the suitability as commercial hybrid for high yield and its attributing characters.

ACKNOWLEDGEMENT

This is part of the author's post-graduate thesis work at Professor Jayashankar Telangana State Agricultural University. The author is highly grateful for the research facilities provided by the Indian Institute of Oilseeds Research, Hyderabad, and Professor Jayashankar Telangana State Agricultural University.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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