



# Character Association Studies for Yield Attributing Traits Across Different Seasons in Pearl Millet [*Pennisetum glaucum* (L.) R. Br]

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## Authors' contributions

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

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## ABSTRACT

The purpose of the present investigation was to assess the association of different characters among 36 advanced hybrids, 12 B lines and 3 R lines with grain yield per plot pooled across the seasons *Kharif* and summer and to demonstrate the direct and indirect effects of various characters on grain yield. The results on correlation in the present study revealed that, in general, the genotypic correlation coefficients were higher than their corresponding phenotypic correlations. Grain yield had genotypically significant positive correlation with most of the characters under study

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viz. plant height (0.955), effective tillers per plant (0.848), flag leaf length (0.992), flag leaf width (0.985), leaf length (0.987), leaf width (0.971), panicle length (0.234), panicle width (0.153), maximum PS II efficiency (0.215), fresh biomass (0.994), dry biomass (0.993), harvest index (0.997), 1000 seed weight (0.990) across the two seasons indicating any increase in these traits will increase the yield. The genotypic path analysis revealed high positive direct effect on grain yield per plot with respect to plant height, panicle width, actual PS II efficiency, fresh biomass, dry biomass and 1000 seed weight indicating importance of these characters, which can be strategically used to improve the yield of pearl millet.

**Keywords:** Pearl millet; grain yield; genotypic path analysis; breeding; genetic studies.

## 1. INTRODUCTION

Pearl millet (*Pennisetum glaucum*) is indeed a significant and ancient cereal crop. Its origin in Africa highlight its adaptation to harsh environments and its long history of cultivation. Being a diploid with a chromosomal number of  $2n = 14$  [1] it has a relatively simple genome compared to some other cereals, which can facilitate breeding and genetic studies. Its nutritional profile, including high levels of protein, fiber, and essential minerals, further enhances its value as a staple crop in various regions. Its ability to thrive in harsh and marginal environments makes it an essential crop for food security in challenging regions. Its resilience to drought and ability to grow in low-rainfall conditions (150-700 mm annually) further enhances its role in sustainable agriculture. With a production of 36 million tons, it is grown on roughly 27 million ha in more than 30 countries, with the majority of crop area reported in Asia (>10 million ha) and Africa (approximately 18 million ha) [2]. With an area of about 7.57 million ha, 10.86 million tonnes of production on average, and productivity of 1436 kg ha<sup>-1</sup>, India is the world's top producer of pearl millet [3]. It is grown in the areas of Andhra Pradesh, Uttar Pradesh, Gujarat, Haryana, Maharashtra, Karnataka, and Telangana. In pearl millet and all

other crop plants, grain production is a quantitative trait that is polygenetically controlled. Grain yield character selection alone is not particularly effective or efficient; selection based on its components and secondary characters may be more successful and dependable. The characteristics that contribute to grain yield are identified by the correlation coefficient analysis, which also assesses the strength and direction of the association between plant attributes. Path analysis is helpful in indirect selection since it tells us about the direct and indirect effects of independent factors on the dependent variable and helps identify the characters that contribute to yield.

## 2. MATERIALS AND METHODS

The experimental material for the present investigation comprises of 36 Hybrids with a single standard check (Kaveri Super Boss) 12 B lines and 3 R lines (Table 1) of pearl millet developed at ICAR-Indian Institute of Millets Research, Hyderabad evaluated in a randomized block design with three replications during *kharif* of 2022 and summer of 2023. Each entry was sown in two rows of 3m length at a spacing of 45 cm × 15 cm. Observations were recorded on five competitive plants in each genotype in each replication for days to 50% flowering,

**Table 1. List of lines, testers and hybrids used in the experiment**

Lines	Testers	Hybrids
04999B	123R	04999B × 123R
	124R	04999B × 124R
	132R	04999B × 132R
843-22B	123R	843-22B × 123R
	124R	843-22B × 124R
	132R	843-22B × 132R
221B	123R	221B × 123R
	124R	221B × 124R
	132R	221B × 132R
242B	123R	242B × 123R
	124R	242B × 124R
	132R	242B × 132R

Lines	Testers	Hybrids
246B	123R	246B × 123R
	124R	246B × 124R
	132R	246B × 132R
252B	123R	252B × 123R
	124R	252B × 124R
	132R	252B × 132R
260B	123R	260B × 123R
	124R	260B × 124R
	132R	260B × 132R
262B	123R	262B × 123R
	124R	262B × 124R
	132R	262B × 132R
264B	123R	264B × 123R
	124R	264B × 124R
	132R	264B × 132R
269B	123R	269B × 123R
	124R	269B × 124R
	132R	269B × 132R
274B	123R	274B × 123R
	124R	274B × 124R
	132R	274B × 132R
291B	123R	291B × 123R
	124R	291B × 124R
	132R	291B × 132R

days to maturity, plant height (cm), number of effective tillers per plant, flag leaf length (cm), flag leaf width (cm), leaf length (cm), leaf width (cm), actual photosystem II efficiency ( $\Phi$ PSII), maximum photosystem II efficiency ( $F_v/F_m$ ), panicle length (cm), panicle width (cm), fresh biomass (kg/plot), dry biomass (kg/plot), grain yield (kg/plot), harvest index (%) and 1000 seed weight (gm). The genotypic correlations between yield and its component traits and among themselves were worked out as per the methods suggested by Al-Jibouri et al. [4]. Path coefficient analysis was carried out as suggested by Wright [5] and Dewey and Lu [6]. The simple correlation coefficients already estimated at genotypic level were utilized for this purpose. By keeping yield as dependent variable and other sixteen characters as independent variables, various direct and indirect effects were estimated.

### 3. RESULTS AND DISCUSSION

#### 3.1 Correlation Studies

The purpose of a correlational study is to establish the presence or absence of relationship among the different characters used in the study. This association may be due to pleiotropic action or linkage or both. The pattern of association among the yield contributing traits helps to determine superior genotypes from genetically divergent population based on the interconnection between them. Here in this case the character association is worked out under

pooled conditions. In general the genotypic correlation is much higher than phenotypic correlation for most of the traits (Table 2), indicating that inherent association between various characters studied. Grain yield per plot exhibited highly significant positive correlation with plant height (0.955, 0.809), effective tillers per plant (0.848, 0.712), flag leaf width (0.985, 0.839), leaf length (0.987, 0.660), leaf width (0.971, 0.689), panicle length (0.234, 0.153), panicle width (0.153, 0.107), maximum PS II efficiency (0.215, 0.136), fresh biomass (0.994, 0.900), dry biomass (0.993, 0.897), harvest index (0.997, 0.785), 1000 seed weight (0.990, 0.913) number whereas, days to maturity (-0.982, 0.904), days to 50% flowering (-0.177, -0.112), flag leaf length (-0.992, -0.793), actual PS II efficiency (-0.976, -0.905) which showed highly significant negative correlation at both genotypic and phenotypic levels. The similar result obtained by Choudhary et al. [7] in pearl millet for plant height, effective tillers per plant and days to 50% flowering, Ezeaku et al. [8] for plant height and panicle length. Similar results were reported for grain yield with 1000 seed weight by Gupta et al. [9] and Sankar et al. [10] and with Harvest index by Arya et al. [11], Kumar et al. [12], Dapke et al. [13] and Abuali et al. [14].

#### 3.2 Path Coefficient Analysis

Studying the path co-efficient analysis, which considers both the causal and degree



**Table 2. Genotypic ( $r_g$ ) and Phenotypic ( $r_p$ ) correlation coefficient for grain yield and other traits in pearl millet**

Characters	$r_g/r_p$	Days to 50% flowering	Days to maturity	Plant Height (cm)	Effective tillers/ plant	Flag leaf length (cm)	Flag leaf width (cm)	Leaf length (cm)	Leaf width (cm)	Panicle length (cm)
Days to 50% flowering	$r_g$	1	0.218**	-0.121*	-0.162**	0.207**	-0.179**	-0.307**	-0.163**	0.206**
	$r_p$	1	0.172 **	-0.096	-0.092	0.145 *	-0.133*	-0.110	-0.057	0.103
Days to maturity	$r_g$		1	-0.912**	-0.808**	0.994**	-0.977**	-0.899**	-0.995**	-0.194**
	$r_p$		1	-0.761 **	-0.668 **	0.777 **	-0.820 **	-0.621 **	-0.673 **	-0.128 *
Plant Height (cm)	$r_g$			1	0.829**	-0.956**	0.970**	0.959**	0.976**	0.357**
	$r_p$			1	0.663**	-0.710 **	0.765 **	0.589 **	0.638 **	0.275 **
Effective tillers/plant	$r_g$				1	-0.876**	0.843**	0.926**	0.889**	0.185**
	$r_p$				1	-0.628 **	0.667 **	0.518 **	0.573 **	0.102
Flag leaf length (cm)	$r_g$					1	-0.965**	-0.956**	-0.995**	-0.198**
	$r_p$					1	-0.711 **	-0.509 **	-0.557**	-0.112 *
Flag leaf width (cm)	$r_g$						1	0.956**	0.968**	0.277**
	$r_p$						1	0.698 **	0.737 **	0.183 **
Leaf length (cm)	$r_g$							1	0.964**	0.269**
	$r_p$							1	0.722 **	0.162 **
Leaf width (cm)	$r_g$								1	0.316**
	$r_p$								1	0.132 *
Panicle length (cm)	$r_g$									1
	$r_p$									1
Panicle width (cm)	$r_g$									
	$r_p$									
Actual PS II efficiency ( $\Phi$ PSII)	$r_g$									
	$r_p$									
Maximum PS II efficiency ( $F_v/F_m$ )	$r_g$									
	$r_p$									
Fresh biomass (kg/plot)	$r_g$									
	$r_p$									
Dry biomass (kg/plot)	$r_g$									
	$r_p$									
Harvest index (%)	$r_g$									
	$r_p$									
1000 seed weight (g)	$r_g$									
	$r_p$									
Grain yield (kg/plot)	$r_g$									
	$r_p$									

Table 2 (Continued). Genotypic ( $r_g$ ) and Phenotypic ( $r_p$ ) correlation coefficient for grain yield and other traits in pearl millet

Characters	$r_g/r_p$	Panicle width (cm)	Actual PS II efficiency ( $\Phi$ PSII)	Maximum PS II efficiency ( $F_v/F_m$ )	Fresh biomass (kg/plot)	Dry biomass (kg/plot)	Harvest index (%)	1000 seed weight (g)	Grain yield (kg/plot)
Days to 50% flowering	$r_g$	0.384**	0.237**	0.342**	-0.192**	-0.198**	-0.252**	-0.237	-0.177**
	$r_p$	0.219 **	0.184 **	0.161**	-0.137 *	-0.133 *	-0.150 **	-0.190 **	-0.112*
Days to maturity	$r_g$	-0.101	0.953**	-0.164**	-0.966**	-0.961**	-0.971**	-0.957**	-0.982**
	$r_p$	-0.067	0.896 **	-0.103	-0.875**	-0.864 **	-0.763 **	-0.884 **	-0.904**
Plant Height (cm)	$r_g$	0.306**	-0.919**	0.428**	0.928**	0.915**	0.858**	0.941**	0.955**
	$r_p$	0.223 **	-0.808 **	0.266 **	0.794 **	0.805 **	0.643 **	0.810**	0.809**
Effective tillers/plant	$r_g$	0.232**	-0.840**	0.351**	0.816**	0.839**	0.789**	0.811**	0.848**
	$r_p$	0.133 *	-0.733 **	0.226 **	0.685 **	0.711**	0.579 **	0.710 **	0.712**
Flag leaf length (cm)	$r_g$	-0.190**	0.950**	-0.237**	-0.985**	-0.941**	-0.989**	-0.993**	-0.992**
	$r_p$	-0.108	0.838 **	-0.157 **	-0.770 **	-0.792 **	-0.634 **	-0.784 **	-0.793**
Flag leaf width (cm)	$r_g$	0.201**	-0.980**	0.299**	0.998**	0.997**	0.967**	0.997**	0.985**
	$r_p$	0.116 *	-0.852 **	0.110	0.836**	0.833 **	0.732**	0.852 **	0.839**
Leaf length (cm)	$r_g$	0.157**	-0.980**	0.180**	0.989**	0.984**	0.926**	0.990**	0.987**
	$r_p$	0.105	-0.639 **	0.080	0.664 **	0.636 **	0.563 **	0.648 **	0.660**
Leaf width (cm)	$r_g$	0.267**	-0.970**	0.313**	0.992**	0.931**	0.994**	0.953**	0.971**
	$r_p$	0.097	-0.686 **	0.097	0.679 **	0.680 **	0.598 **	0.685 **	0.689**
Panicle length (cm)	$r_g$	0.767**	-0.179**	0.411**	0.226**	0.177**	0.139*	0.193**	0.234**
	$r_p$	0.703 **	-0.120 *	0.243 **	0.139*	0.104	0.043	0.144 *	0.153**
Panicle width (cm)	$r_g$	1	-0.168**	0.801**	0.111*	0.119*	-0.077	0.113*	0.153**
	$r_p$	1	-0.1	0.414 **	0.083	0.090	-0.067	0.093	0.107
Actual PS II efficiency ( $\Phi$ PSII)	$r_g$		1	-0.220**	-0.952**	-0.970**	-0.929**	-0.954**	-0.976**
	$r_p$		1	-0.118 *	-0.889 **	-0.909 **	-0.774 **	-0.914 **	-0.905**
Maximum PS II efficiency ( $F_v/F_m$ )	$r_g$			1	0.200**	0.224**	-0.008	0.192**	0.215**
	$r_p$			1	0.116 *	0.152 **	-0.308 **	0.106	0.136*
Fresh biomass (kg/plot)	$r_g$				1	0.974**	0.993**	0.986**	0.994**
	$r_p$				1	0.883 **	0.786 **	0.914 **	0.900**
Dry biomass (kg/plot)	$r_g$					1	0.962**	0.969**	0.993**
	$r_p$					1	0.834 **	0.890 **	0.897**
Harvest index (%)	$r_g$						1	0.977**	0.997**
	$r_p$						1	0.795 **	0.785**
1000 seed weight (g)	$r_g$							1	0.990**
	$r_p$							1	0.913**
Grain yield (kg/plot)	$r_g$								1
	$r_p$								1

\* $p < 0.05$  and \*\* $p < 0.01$ ,  $r_g$  is genotypic correlation coefficient,  $r_p$  is phenotypic correlation coefficient

Table 3. Genotypic (G) and Phenotypic (p) path coefficient analysis for grain yield and its component characters in pearl millet

Characters	G/P	Days to 50% 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)	Panicle length (cm)
Days to 50% flowering	G	<b>0.0349</b>	0.0076	-0.0042	-0.0057	0.0072	-0.0063	-0.0107	-0.0057	0.0072
	P	<b>0.0462</b>	0.0080	-0.0045	-0.0043	0.0067	-0.0062	-0.0051	-0.0027	0.0048
Days to maturity	G	-0.1312	<b>-0.6000</b>	0.5472	0.4848	-0.6027	0.5867	0.6594	0.5972	0.1169
	P	-0.0470	<b>-0.2727</b>	0.2076	0.1822	-0.2120	0.2237	0.1693	0.1837	0.0351
Plant Height (cm)	G	-0.0415	-0.3131	<b>0.3433</b>	0.2846	-0.3282	0.3331	0.3635	0.3352	0.1227
	P	-0.0052	-0.0412	<b>0.0542</b>	0.0359	-0.0385	0.0415	0.0319	0.0346	0.0149
Effective tillers per plant	G	-0.0163	-0.0809	0.0830	<b>0.1001</b>	-0.0877	0.0845	0.0927	0.0890	0.0186
	P	-0.0030	-0.0214	0.0213	<b>0.0320</b>	-0.0201	0.0214	0.0166	0.0184	0.0033
Flag leaf length (cm)	G	0.0341	0.1652	-0.1572	-0.1441	<b>0.1644</b>	-0.1752	-0.1999	-0.1835	-0.0326
	P	-0.0078	-0.0415	0.0379	0.0335	<b>-0.0534</b>	0.0380	0.0272	0.0298	0.0060
Flag leaf width (cm)	G	0.0086	0.0468	-0.0465	-0.0404	0.0510	<b>-0.0479</b>	-0.0506	-0.0464	-0.0133
	P	-0.0018	-0.0113	0.0105	0.0092	-0.0098	<b>0.0137</b>	0.0096	0.0101	0.0025
Leaf length (cm)	G	-0.0014	-0.0051	0.0050	0.0043	-0.0057	0.0049	<b>0.0047</b>	0.0055	0.0013
	P	-0.0052	-0.0291	0.0276	0.0243	-0.0239	0.0327	<b>0.0468</b>	0.0338	0.0076
Leaf width (cm)	G	0.0457	0.2778	-0.2725	-0.2483	0.3114	-0.2704	-0.3250	<b>-0.2791</b>	-0.0884
	P	0.0004	0.0049	-0.0047	-0.0042	0.0041	-0.0054	-0.0053	<b>-0.0073</b>	-0.0010
Panicle length (cm)	G	-0.0272	0.0256	-0.0471	-0.0244	0.0261	-0.0365	-0.0355	-0.0417	<b>-0.1316</b>
	P	0.0012	-0.0014	0.0031	0.0011	-0.0013	0.0020	0.0018	0.0015	<b>0.0112</b>
Panicle width (cm)	G	0.1236	-0.0327	0.0986	0.0747	-0.0611	0.0648	0.0505	0.0858	0.2466
	P	-0.0025	0.0008	-0.0026	-0.0015	0.0013	-0.0013	-0.0012	-0.0011	-0.0081
Actual PS II efficiency	G	0.1007	0.4042	-0.3900	-0.3565	0.4455	-0.4156	-0.4709	-0.4285	-0.0763
	P	-0.0131	-0.0637	0.0575	0.0521	-0.0595	0.0605	0.0454	0.0488	0.0085
Maximum PS II efficiency	G	-0.1409	0.0678	-0.1765	-0.1446	0.0979	-0.1231	-0.0742	-0.1292	-0.1694
	P	0.0060	-0.0038	0.0099	0.0084	-0.0058	0.0041	0.0030	0.0036	0.0090
Fresh biomass (kg/plot)	G	-0.1046	-0.5247	0.5041	0.4430	-0.5458	0.5417	0.6024	0.5389	0.1228
	P	-0.0165	-0.1052	0.0956	0.0824	-0.0926	0.1005	0.0798	0.0817	0.0168
Dry biomass (kg/plot)	G	-0.1951	-0.9451	0.9001	0.8255	-1.0240	0.9800	1.0858	1.0140	0.1741
	P	-0.0120	-0.0776	0.0724	0.0639	-0.0711	0.0748	0.0571	0.0611	0.0094
Harvest index (%)	G	0.1680	0.6457	-0.5706	-0.5244	0.6573	-0.6428	-0.7483	-0.6608	-0.0925
	P	-0.0129	-0.0653	0.0551	0.0496	-0.0542	0.0626	0.0482	0.0512	0.0037
1000 seed weight (gm)	G	-0.0349	-0.1412	0.1388	0.1196	-0.1478	0.1471	0.1637	0.1508	0.0286
	P	-0.0395	-0.1836	0.1683	0.1476	-0.1630	0.1770	0.1347	0.1423	0.0299

Table 3 (Continued). Genotypic (G) and Phenotypic (P) path coefficient analysis for grain yield and its component characters in pearl millet

Characters	G/P	Panicle width (cm)	Actual PS II efficiency ( $\Phi$ PSII)	Maximum PS II efficiency ( $F_v/F_m$ )	Fresh biomass (kg/plot)	Dry biomass (kg/plot)	Harvest index (%)	1000 seed weight (gm)	Grain yield (kg/plot) $r_g/r_p$
Days to 50% flowering	G	0.0134	0.0083	0.0120	-0.0067	-0.0069	-0.0088	-0.0083	-0.177**
	P	0.0101	0.0085	0.0075	-0.0063	-0.0062	-0.0070	-0.0088	-0.112*
Days to maturity	G	0.0611	-0.5719	0.0988	0.5800	0.5769	0.5832	0.5747	-0.982**
	P	0.0183	-0.2443	0.0281	0.2387	0.2357	0.2081	0.2410	-0.904**
Plant Height (cm)	G	0.1053	-0.3157	0.1472	0.3188	0.3143	0.2948	0.3233	0.955**
	P	0.0121	-0.0438	0.0144	0.0430	0.0436	0.0349	0.0439	0.809**
Effective tillers per plant	G	0.0233	-0.0842	0.0352	0.0817	0.0841	0.0790	0.0812	0.848**
	P	0.0043	-0.0235	0.0073	0.0220	0.0228	0.0186	0.0228	0.712**
Flag leaf length (cm)	G	-0.0313	0.1728	-0.0391	-0.1654	-0.1713	-0.1627	-0.1649	-0.992**
	P	0.0058	-0.0448	0.0084	0.0411	0.0423	0.0339	0.0419	-0.793**
Flag leaf width (cm)	G	-0.0097	0.0470	-0.0143	-0.0478	-0.0478	-0.0463	-0.0478	0.985**
	P	0.0016	-0.0117	0.0015	0.0115	0.0114	0.0101	0.0117	0.839**
Leaf length (cm)	G	0.0007	-0.0052	0.0008	0.0052	0.0052	0.0053	0.0052	0.987**
	P	0.0049	-0.0299	0.0038	0.0311	0.0298	0.0264	0.0303	0.66**
Leaf width (cm)	G	-0.0746	0.2821	-0.0876	-0.2771	-0.2879	-0.2776	-0.2855	0.971**
	P	-0.0007	0.0050	-0.0007	-0.0050	-0.0050	-0.0044	-0.0050	0.689**
Panicle length (cm)	G	-0.1010	0.0237	-0.0542	-0.0298	-0.0233	-0.0183	-0.0255	0.234**
	P	0.0079	-0.0013	0.0027	0.0016	0.0012	0.0005	0.0016	0.153**
Panicle width (cm)	G	<b>0.3213</b>	-0.0542	0.2575	0.0360	0.0384	-0.0249	0.0364	0.153**
	P	<b>-0.0116</b>	0.0012	-0.0048	-0.0010	-0.0010	0.0008	-0.0011	0.107
Actual PS II efficiency ( $\Phi$ PSII)	G	-0.0715	<b>0.4240</b>	-0.0935	-0.4039	-0.4116	-0.3943	-0.4047	-0.976**
	P	0.0071	<b>-0.0710</b>	0.0084	0.0632	0.0646	0.0550	0.0650	-0.905**
Maximum PS II efficiency ( $F_v/F_m$ )	G	-0.3299	0.0907	<b>-0.4116</b>	-0.0827	-0.0924	0.0036	-0.0794	0.215**
	P	0.0153	-0.0044	<b>0.0370</b>	0.0043	0.0056	-0.0114	0.0039	0.136*
Fresh biomass (kg/plot)	G	0.0608	-0.5170	0.1091	<b>0.5428</b>	0.5289	0.5391	0.5353	0.994**
	P	0.0101	-0.1069	0.0140	<b>0.1202</b>	0.1062	0.0946	0.1099	0.900**
Dry biomass (kg/plot)	G	0.1174	-0.9540	0.2206	0.9578	<b>0.9830</b>	0.9461	0.9531	0.993**
	P	0.0081	-0.0817	0.0137	0.0793	<b>0.0898</b>	0.0749	0.0800	0.897**
Harvest index (%)	G	0.0515	0.6178	0.0058	-0.6599	-0.6395	<b>-0.6644</b>	-0.6497	0.997**
	P	-0.0058	-0.0663	-0.0264	0.0673	0.0713	<b>0.0855</b>	0.0680	0.785**
1000 seed weight (gm)	G	0.0167	-0.1407	0.0284	0.1453	0.1429	0.1441	<b>0.1474</b>	0.990**
	P	0.0195	-0.1901	0.0221	0.1899	0.1851	0.1652	<b>0.2077</b>	0.913**



#### 4. CONCLUSION

The studies on correlation coefficient indicated that the characters viz. plant height, effective tillers per plant, flag leaf width, leaf length, leaf width, fresh biomass, dry biomass, harvest index and 1000 seed weight recorded high significant positive correlation on grain yield per plot. Similarly, path coefficient analysis revealed that the character dry biomass exhibited highest positive direct effect on grain yield per plot followed by fresh biomass, actual PS II efficiency, plant height and panicle width. Based on these studies, plant height, effective tillers per plant, panicle width, leaf length, fresh biomass, dry biomass and 1000 seed weight were the predominant yield contributing characters in pearl millet.

#### DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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