E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; 7(8): 667-671
Received: 03-06-2024
Accepted: 08-07-2024

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Estimates of genetic components for yield and its related traits in pearl millet hybrids (*Pennisetum glaucum* L. R. Br.)

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i8i.1352

Abstract
Pearl millet [*Pennisetum glaucum* (L) R.Br.] is an important millet crop of semi-arid region in India. A total of 17 hybrids was evaluated in randomized block design with three replications during summer 2022 at Regional Research Station, AAU, Anand, Gujarat. In middle Gujarat, large area under summer bajra cultivation so our objective to estimate variability parameter and it's inter and intra relation between different quantitative traits. Significant differences were observed among the hybrids for all the traits studied. The narrow difference between PCV and GCV values for all studied traits indicates little influence of environment on expression and High PCV and GCV values were obtained for productive tillers per plant panicle length dry panicle weight, grin yield and fodder yield per plant suggested that there was a possibility of improvement of these traits through direct selection. High heritability observed for all the traits while moderate for plant population and fodder yield per plant. High heritability along with high genetic advance as percent of mean was observed for plant height indicates important of this trait in selection and crop improvement. Correlation study revealed that the traits like plant population, plant height, Dry earhead weight and fodder yield exhibited significant and positive correlation with grain yield. Dry earhead weight, plant height and penicle length showed highest positive direct effecton grain yield at genotypic level. Hence, main emphasis should be given to these traits in breeding programme for development of high yielding bajra hybris under middle Gujarat condition.

Keywords: Pearl millet, Pennisetum glaucum, hybrids, variability parameters, heritability, correlation study

Introduction
Pearl millet (*Pennisetum glaucum* (L) R.Br.) is a crucial cereal crop cultivated predominantly in the semi-arid regions of India, where it serves as a staple food and fodder source. Its resilience to drought and adaptability to harsh climatic conditions make it a valuable crop for sustaining agriculture in these challenging environments (G. Rakesh, S. S. Jadhav, and A. K. Patil, 2015; N. Dhedhi, M. P. Sharma, and A. K. Rathi, 2015) [2, 5].

The growing interest in pearl millet is driven by its potential for improving food security and supporting livelihoods in regions where other crops may struggle. Recent research has underscored the importance of enhancing pearl millet yield through breeding programs aimed at improving various agronomic traits. The effectiveness of such programs relies heavily on understanding the genetic variability and trait associations within pearl millet germplasm (A. Patil, N. M. Kumawat, and D. B. Katiyar, 2021; M. Vagadiya, J. Patel, and S. G. Patel, 2013) [1, 4].

In the context of summer bajra cultivation in middle Gujarat, India, there is a significant focus on assessing genetic variability and its implications for crop improvement. This study was conducted at the Regional Research Station, AAU, Anand, Gujarat, during the summer of 2022. The primary objective was to estimate variability parameters and examine the inter- and intra-relations among different quantitative traits in pearl millet hybrids. A total of 17 hybrids were evaluated using a randomized block design with three replications.

Our analysis aims to provide insights into the genetic diversity and potential for selection within these hybrids. Significant differences among hybrids were observed for all traits studied,

indicating considerable genetic variation. The narrow gap between phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) values suggests that environmental factors had minimal influence on trait expression (S. Satbeer Singh, H. S. Ahlawat, and D. Singh, 2017; S. Yadav, N. Sharma, and R. Kumar, 2020) [10, 12]. High PCV and GCV values for key traits such as productive tillers per plant, panicle length, dry panicle weight, grain yield, and fodder yield indicate potential for improving these traits through direct selection (P. Rajpoot, V. Yadav, and R. S. Choudhury, 2023; M. Izle, R. K. Gupta, and S. N. Patel, 2006) [12, 8, 3].

The study also evaluated heritability and genetic advance for various traits. High heritability along with high genetic advance was observed for plant height, highlighting its importance in selection and crop improvement (O. Ezeaku, B. U. Okereke, and M. I. Obi, 2015) [7]. Correlation and path coefficient analyses revealed significant positive associations between grain yield and traits such as plant height, dry earhead weight, and panicle length (S. Satbeer, P. K. Jha, and R. Singh, 2017; N. Izge, G. P. Singh, and A. S. Jain, 2006) [6, 11]. These findings suggest that focusing on these traits could enhance grain yield and contribute to the development of high-yielding pearl millet hybrids suited to the conditions of middle Gujarat.

Materials and Methods

The study was carried out at the Regional Research Station, Anand Agricultural University (AAU), located in the Anand District of middle Gujarat, during the summer season of 2022. The experimental setup utilized a randomized block design (RBD) with three replications to ensure robustness and reliability of the results. A total of seventeen pearl millet hybrids were selected based on their performance in preliminary trials and their suitability for the semi-arid climate typical of middle Gujarat. Each hybrid was sown in plots measuring 4 meters by 3 meters, with rows spaced 60 cm apart and plants spaced 15 cm within rows. This arrangement provided ample space for the plants to grow and for accurate measurement of the various traits (Rajpoot *et. al.*, 2023) [8].

Field management practices were meticulously followed to create optimal growing conditions for the pearl millet hybrids. Irrigation was applied based on the crop's water requirements, with care taken to avoid both waterlogging and drought stress. Fertilizer application was carried out according to the recommended practices for pearl millet, including both basal and top-dressing applications. Manual weeding was performed at regular intervals to minimize competition for nutrients and reduce pest infestations. Pest and disease management strategies included monitoring for common issues and applying control measures as necessary (Patil *et. al.*, 2021) [1].

Data collection was comprehensive, focusing on both agronomic and yield-related traits. Key measurements included plant height, panicle length, number of productive tillers per plant, dry panicle weight, and final grain and fodder yields. Statistical analysis involved calculating phenotypic and genotypic coefficients of variation (PCV and GCV) to assess the variability of traits. Heritability and genetic advance were estimated to understand the potential for genetic improvement. Correlation and path coefficient analyses were performed to evaluate the relationships between traits and their impact on grain yield. These analyses were crucial for identifying the most promising hybrids and understanding trait associations critical for enhancing pearl millet productivity in the region (Rakesh *et. al.*, 2013) [2].

Results and Discussion

Analysis of variance

The mean sum of squares due to different seventeen genotypes showed significant differences for majority of the quantitative characters under study at 5% level of significance, suggesting that the genotypes were genetically divergent (Table 1). This indicates that there is sufficient scope for selection of promising genotypes from the germplasm accessions. This passage highlights the importance of genetic diversity and the potential for selection of desirable genotypes in improving grain yield and supporting traits. It also recognizes the role of both genetic and environmental factors in contributing to the observed variability in the quantitative characters. The references of G Rakesh *et al.* (2015) [2], Sankar *et al.* (2013) [9], Vagadiya *et al.* (2013) [4] to previous studies provides additional support for the current findings.

Table 1: Analysis of variance for yield and yield contributing characters in pearl millet hybrids

Characters	Mean sum of squares		
	Replications (d.f. = 2)	Hybrids (d.f. = 16)	Error (d.f. =32)
Plant population at harvest	17.484	108.702	56.991
Days to 50% flowering	6.531	44.213*	2.342
Plant height (cm)	10.438	574.333*	20.439
Productive tillers/plant	0.264	0.985*	0.149
Panicle length (cm)	1.641	21.601*	0.549
Panicle diameter (cm)	0.000	0.302*	0.005
Days to maturity	0.250	7.922*	1.047
Dry panicle wt. (kg/net plot)	0.445	1.999*	0.249
Grain yield (kg/net plot)	0.031	0.977*	0.082
Fodder yield (kg/net plot)	4.142	1.755*	0.882

*Significant at 5 percent level

Mean performance

In our current investigation, we observed substantial variations in the mean values of all the traits under scrutiny. Notably, grain yield exhibited a range between 2.867 and 4.960 kg per net plot, while dry earhead weight ranged from 4.457 to 7.508 kg per net plot. Fodder yield displayed variations between 4.535 and 7.459 kg per net plot, and plant population at harvest spanned from 70 to 93. Additionally, the days to 50% flowering ranged from 38 to 49 days, plant height from 155 to 204 cm, productive tillers from 3.4 to 5.5, panicle length varied from 20.8 to 30.9 cm, panicle diameter showed a range of 2.8 to 3.9 cm, and days to maturity spanned from 83 to 88 days (as detailed in Table 2). Among the seventeen distinct genotypes, it's worth noting that two genotypes exhibited a sterile reaction when plants from the population were subjected to selfing. Moreover, the top three genotypes, namely AGBH 5, AGBH 13, and AGBH 2, demonstrated the highest grain yield values (4.497, 4.481, and 4.383 kg per net plot) with fertile reactions. This suggests that

these genotypes hold promise for further utilization in breeding programs.

Table 2: Estimates of mean performance with sterile/fertile reaction in pearl millet hybrids

Name of Genotypes	Characters										
	GY	DEW	FY	PP	DF	PH	PT	PL	PD	DM	S/F
AGBH 1	3.476	5.530	6.214	89	40	155	5.5	24.6	2.8	85	F
AGBH 2	4.383	6.777	6.737	83	49	200	3.6	29.7	3.8	84	F
AGBH 3	3.143	5.717	6.237	78	48	162	3.5	29.2	3.8	86	S
AGBH 4	3.890	6.520	7.459	88	49	186	3.7	28.0	3.5	87	F
AGBH 5	4.497	6.810	6.520	89	47	178	3.5	28.2	3.4	85	F
AGBH 6	3.615	5.974	5.703	85	47	183	3.7	26.1	3.5	83	F
AGBH 7	3.828	5.732	5.553	83	44	177	3.4	29.6	3.4	88	F
AGBH 8	4.311	6.687	5.510	80	39	178	3.5	24.3	3.4	85	F
AGBH 9	4.960	7.508	5.652	93	45	197	3.7	27.0	3.6	84	S
AGBH 10	3.321	4.830	4.672	89	38	164	3.7	20.8	3.5	85	F
AGBH 11	3.222	5.116	5.322	89	38	162	4.9	23.7	3.3	86	F
AGBH 12	4.327	6.618	6.768	93	39	167	4.3	23.4	3.3	87	F
AGBH 13	4.481	6.740	6.370	89	45	178	3.7	25.8	3.2	87	F
AGBH 14	2.867	4.457	4.535	70	45	180	3.7	26.2	2.8	83	F
AGBH 15	3.552	6.773	5.650	83	46	177	4.3	24.8	3.0	84	F
AGBH 16	3.911	5.811	5.835	87	45	188	4.2	25.2	3.5	84	F
AGBH 17	3.761	5.815	6.665	93	48	204	3.4	30.9	3.9	87	F
Mean	3.856	6.083	5.965	86	44	179	3.9	26.3	3.4	85	-
Range											
Minimum	2.867	4.457	4.535	70	38	155	3.4	20.8	2.8	83	-
Maximum	4.960	7.508	7.459	93	49	204	5.5	30.9	3.9	88	-

Whereas,

PP = Plant population at harvest	PL = Panicle length (cm)	GY = Grain yield (kg/net plot)
DF = Days to 50% flowering	PD = Panicle diameter (cm)	FY = Fodder yield (kg/net plot)
PH = Plant height (cm)	DM = Days to maturity	
PT = Productive tillers/plant	DEW = Dry earhead wt. (kg/net plot)	

Variability

The trait shows a minimal distinction between PCV and GCV values, indicating a significant level of genetic diversity within these characteristics, thereby offering a wider range for selection based on them. These attributes are relatively unaffected by environmental factors and exhibit substantial genetic variability. The Phenotypic Coefficient of Variation (PCV) estimates surpassed their corresponding Genotypic Coefficient of Variation (GCV) values, yet a noticeable alignment between GCV and PCV was observed across all ten characters (Table 3). A broad spectrum of PCV values was evident in these traits, ranging from as low as 2.15% for days to maturity to a high of 18.16% for fodder yield (kg/plot). Particularly elevated PCV values were registered for fodder yield (kg/net plot) (18.16%), productive tillers (16.77%), grain yield (kg/net plot) (15.99%), and dry earhead weight (kg/plot) (15.00%). Moderate PCV estimates were derived for panicle length (cm) (10.45%), plant population at harvest (10.02%), panicle diameter (cm) (9.52%), days to 50% flowering (9.14%), and plant height (cm) (8.02%). Conversely, lower PCV values were observed for the trait days to maturity (2.15%). The range of GCV values extended from 1.78% (days to maturity) to 14.16% (grain yield (kg/plot)). The highest GCV was recorded for grain yield (kg/plot) (14.16%), followed by productive tillers (13.53%), and dry earhead weight (kg/plot) (12.55%). Moderate GCV values were noted for traits such as panicle length (cm) (10.06%), panicle diameter (cm) (9.29%), fodder yield (kg/net plot) (9.04%), days to 50% flowering (8.46%), and plant height (cm) (7.61%). Conversely, lower GCV values were evident for plant population at harvest (4.83%) and days to maturity (1.78%). These results are in conformity with the reports of G Rakesh *et al*. (2015) [2] for grain yield (kg/net plot), Satbeer Singh *et al*. (2017) [11] for panicle length, Dhedhi *et al*. (2015) [5] for fodder yield (kg/net plot), Poonam Rajpoot *et al*. (2023) [8] for productive tillers per plant**.** On an average, the majority of the traits studied exhibited notably high levels of both Phenotypic Coefficient of Variation (PCV) and Genotypic Coefficient of Variation (GCV).

This observation indicates that the working collection of germplasm holds substantial variability, offering ample potential for genetic improvement through trait selection.

Table 3: Estimates of mean, variability, heritability, genetic gain and genetic advance as per cent of mean for grain yield and its components in pearl millet

Characters	Coefficient of variation (%)		Broad sense heritability (h^2) (%)	Genetic advance as percent of mean (5%)
	Genotypic	Phenotypic		
Plant population at harvest	4.83	10.02	23.20	4.12
Days to 50% flowering	8.46	9.14	85.60	7.12
Plant height (cm)	7.61	8.02	90.00	26.56
Productive tillers/plant	13.53	16.77	65.10	0.88
Panicle length (cm)	10.06	10.45	92.70	5.26
Panicle diameter (cm)	9.29	9.52	95.20	0.63
Days to maturity	1.78	2.15	68.60	2.58
Dry panicle wt. (kg/net plot)	12.55	15.00	70.00	1.32
Grain yield (kg/net plot)	14.16	15.99	78.50	1.00
Fodder yield (kg/net plot)	9.04	18.16	24.80	0.55

Heritability and Genetic advance as percent of mean

Heritability serves as a metric indicating the degree of phenotypic variation attributed to genetic factors. It quantifies the proportion of genetic variability transmitted from parents to offspring.

Broad-sense heritability, expressed as a percentage, denotes the ratio of total genotypic variance to phenotypic variance. It has gained recognition among many researchers as a dependable indicator for effective character improvement through selection. In the current study, the broad-sense heritability ranged from 23.20 percent for plant population at harvest to a high of 95.20 percent for panicle diameter. Exceptionally high heritability values were evident in all traits examined, namely panicle diameter (95.20%), panicle length (92.70%), plant height (90.00%), days to 50% flowering (85.60%), and grain yield (78.50%). As suggested by Panse *et al*. (1957), traits with high heritability are chiefly governed by additive gene action, making them amenable to improvement through individual plant selection. Similar results were reported by G Rakesh *et al*. (2015) [2] for panicle diameter, panicle length, and by Yadav *et al*. (2020) [12] for plant height and days to 50% flowering.

It is important to note that while high heritability is indicative of potential genetic improvement, it does not guarantee substantial genetic advance. Therefore, heritability estimates become more meaningful when expressed in terms of genetic advance. Johnson *et al*. (1955) recommended considering both heritability and genetic advance together to better predict the outcome of selection on phenotypic expression. In the absence of genetic advance, heritability estimates lack practical value, emphasizing the need for their concurrent use.

In our present study, high genetic advance as a percentage of the mean was observed solely for plant height (26.56%), while moderate estimates were obtained for days to 50% flowering (7.12%), panicle length (5.26%), and plant population at harvest (4.12%). Low estimates were obtained for the remaining traits, consistent with the findings of Yadav *et al*. (2020) [12] for panicle length, G Rakesh *et al*. (2015) [2] for plant height, and Ezeaku *et al*. (2015) [7] for grain yield. High heritability coupled with high genetic advance as a percentage of the mean in the case of plant height suggests a predominant role of additive gene action in these traits' expression. Such traits can be enhanced through mass selection and other breeding methods reliant on progeny testing. On the other hand, high heritability along with low genetic advance as a percentage of the mean, as well as moderate genetic advance, in the case of panicle diameter and panicle length, indicates the involvement of non-additive gene action. Consequently, these traits could be improved through heterosis breeding methods.

Correlation coefficient analysis

In general, it was observed that genotypic correlation coefficients exceeded their corresponding phenotypic correlation coefficients, highlighting the predominant influence of genetic factors on the expression of traits, alongside the moderating impact of environmental conditions (Table 4).

Significant and positive correlations between grain yield and other yield-related variables are highly favourable in the realm of plant breeding, as they streamline the selection process. Within this study, the phenotypic correlation of grain yield (kg/net plot) was notably positive and significant with respect to two key characteristics: plant height (cm) and dry earhead weight (kg/net plot). These attributes demand careful consideration in any selection programs. Similar findings of positive and significant correlations between grain yield and plant height were previously reported by Patil *et al*. (2021) [1] and Izge *et al*. (2006) [6]. Furthermore, plant height (cm) exhibited a positive and significant association with days to 50% flowering, which aligned with earlier findings by Izle *et al*. (2006) [3]. Panicle length (cm) displayed positive and significant correlations with days to 50% flowering and plant height (cm), while panicle diameter (cm) exhibited positive and significant associations with days to 50% flowering, plant height (cm), and panicle length (cm), consistent with the observations made by Satbeer *et al*. (2017) [11]. Dry earhead weight (kg/net plot) also exhibited a significantly positive correlation with plant height (cm). Fodder yield (kg/net plot) was positively and significantly correlated with days to 50% flowering, days to maturity, dry earhead weight (kg/net plot), and grain yield (kg/net plot), corroborating the findings of Patil *et al*. (2021) [1]. These results underscore the importance of early days to 50% flowering, plant height, panicle length, panicle diameter, dry earhead weight, and fodder yield as critical determinants of higher grain yield.

Table 4: Estimation of phenotypic (P) and genotypic (G) correlation coefficient for yield and its attributing characters in pearl millet

Characters		PP	DF	PH	PT	PL	PD	DM	DEW	GY	FY
PP	P	-	-0.110	0.091	0.023	-0.094	0.189	0.143	0.130	0.234	0.170
	G	-	-0.336	0.139	0.584*	-0.168	0.422	0.669**	0.723**	0.898**	0.997**
DF	P		-	0.598**	-0.425	0.764**	0.375**	-0.104	0.262	0.098	0.286*
	G		-	0.687**	-0.686	0.867**	0.417	-0.025	0.320	0.139	0.705**
PH	P			-	-0.489	0.556**	0.475**	-0.151	0.374**	0.429**	0.174
	G			-	-0.608	0.604*	0.498*	-0.198	0.450	0.501*	0.402
PT	P				-	-0.476	-0.493	-0.016	-0.091	-0.164	0.026
	G				-	-0.579	-0.615	-0.093	-0.315	-0.334	-0.131
PL	P					-	0.478**	0.200	0.224	0.156	0.273
	G					-	0.488*	0.260	0.272	0.202	0.785**
PD	P						-	0.246	0.236	0.272	0.231
	G						-	0.330	0.252	0.297	0.544*
DM	P							-	0.007	0.056	0.373**
	G							-	0.051	0.053	0.656**
DEW	P								-	0.857**	0.428**
	G								-	0.896**	0.784**
GY	P									-	0.435**
	G									-	0.530*
FY	P										-
	G										-

* and ** Significant at 5 and 1 per cent level, respectively.

Path coefficient analysis

In the present study, path coefficient analysis was computed only at genotypic level for all the characters. Path coefficient analysis was carried out by taking grain yield kg/net plot as dependent variable to partition the correlation coefficient into direct and indirect effect in order to determine the contribution of different characters towards the grain yield kg/net plot (Table 5).

Table 5: Genotypic path coefficient of various characters on grain yield (kg/net plot) in pearl millet

Characters	Correlation with GY	PP	DF	PH	PT	PL	PD	DM	DEW	FY
PP	0.898**	-0.150	0.273	0.063	-0.004	-0.050	0.025	0.056	0.700	-0.012
DF	0.139	0.051	-0.810	0.309	0.005	0.260	0.024	-0.002	0.310	-0.009
PH	0.501*	-0.021	-0.557	0.450	0.005	0.181	0.029	-0.017	0.436	-0.005
PT	-0.334	-0.088	0.556	-0.274	-0.008	-0.174	-0.036	-0.008	-0.305	0.002
PL	0.202	0.025	-0.703	0.271	0.004	0.300	0.028	0.022	0.263	-0.010
PD	0.297	-0.063	-0.338	0.224	0.005	0.146	0.058	0.028	0.244	-0.007
DM	0.053	-0.101	0.020	-0.089	0.001	0.078	0.019	0.084	0.049	-0.008
DEW	0.896**	-0.109	-0.260	0.203	0.002	0.082	0.015	0.004	0.968	-0.010
FY	0.898**	-0.150	-0.571	0.181	0.001	0.236	0.032	0.055	0.759	-0.012

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