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Jay P Dhanke
PG Scholar, Department of
Agricultural Botany, Genetics and
Plant Breeding, Post Graduate
Institute, Dr. PDKV, Akola,
Maharashtra, India

Dr. DG Kanwade
Professor (CAS) and Office
Incharge, Agriculture Research
Station Buldhana, Dr. PDKV,
Akola, Maharashtra, India

Dr. VL Gawande
Professor and Incharge, Pulses
Research Center, Dr. PDKV,
Akola, Maharashtra, India

Dr. MD Giri
Assistant Professor (CAS),
Department of Agronomy, Post
Graduate Institute, Dr. PDKV,
Akola, Maharashtra, India

Preeti N Tadas
PG Scholar, Department of
Agronomy, Post Graduate
Institute, Dr. PDKV, Akola,
Maharashtra, India

Corresponding Author:

Jay P Dhanke
PG Scholar, Department of
Agricultural Botany, Genetics and
Plant Breeding, Post Graduate
Institute, Dr. PDKV, Akola,
Maharashtra, India

Genetic variability and correlation studies in foxtail millet (*Setaria italica* L.)

Jay P Dhanke, DG Kanwade, VL Gawande, MD Giri and Preeti N Tadas

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Abstract

Foxtail millet (*Setaria italica* L.), one of the oldest domesticated cereals, is valued for its climate resilience, nutritional density, and adaptability to marginal, rainfed tracts, though its productivity remains constrained by a narrow base of improved cultivars. Thirty-three diverse genotypes, along with the check variety PDKV Yashashree, were evaluated in a Randomized Block Design with three replications at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during Kharif 2024–25, for ten quantitative traits. Analysis of variance revealed highly significant ($p < 0.01$) genotypic differences for all traits. Phenotypic coefficient of variation exceeded genotypic coefficient of variation for every character, though the gap was narrow for panicle weight, grain yield per plant, and productive tillers per plant, which also recorded the highest GCV and PCV (>35%), high heritability (>85%), and high genetic advance as per cent of mean (>65%), indicating predominant additive gene action. Grain yield per plant showed strong, significant positive genotypic correlation with panicle weight (0.949), test weight (0.887), panicle length (0.865), productive tillers per plant (0.812), and plant height (0.789). SIFT-12, BFTM-82-14, and BFTM-82-6 emerged as the most promising genotypes for future breeding use.

Keywords: Foxtail millet, genetic variability, heritability, genetic advance, correlation, grain yield

1. Introduction

Rainfed agriculture accounts for nearly 60% of India's total cultivated area, and climate-resilient crops such as millets play a critical role in sustaining production under these conditions (Unified Portal of Agriculture Statistics, DA&FW, 2025–26) ^[18]. Foxtail millet (*Setaria italica* L.), a self-pollinated C4 cereal with a chromosome number of $2n = 2x = 18$, ranks second in global millet production and is valued for its short duration, drought tolerance and nutritional richness, being naturally gluten-free and a good source of protein, dietary fibre, minerals and antioxidants (Hariprasanna, 2017; Singh *et al.*, 2020; Thakre *et al.*, 2023) ^[6, 16, 17]. Despite this potential, average productivity under traditional cultivation remains low (900–1200 kg/ha), largely due to the limited availability of improved, high-yielding cultivars. Genetic improvement of such a complex, environmentally sensitive trait as grain yield requires precise information on the magnitude of genetic variability, the heritable component of that variability, and the pattern of association between yield and its component characters (Johnson *et al.*, 1955; Falconer, 1981) ^[8, 4]. While the genotypic and phenotypic coefficients of variation quantify the extent of variability, heritability and genetic advance together indicate the reliability of selection, and correlation analysis identifies traits that can serve as indirect selection criteria for yield improvement. The present investigation was therefore undertaken to estimate genetic variability, heritability, genetic advance and genotypic–phenotypic correlations among yield and yield-contributing traits in a diverse set of foxtail millet genotypes, with a view to identifying effective selection criteria for future breeding programmes.

2. Materials and Methods

The experimental material comprised thirty-four diverse genotypes of foxtail millet, including the released check variety PDKV Yashashree, evaluated in a Randomized Block Design with three replications during the Kharif season of 2024–25 at the experimental field of the Department of Agricultural Botany, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra.

Observations were recorded on ten quantitative traits, viz., days to 50% flowering, days to maturity, plant height (cm), productive tillers per plant, panicle length (cm), peduncle length (cm), panicle weight (g), straw yield per plant (g), test weight (g), and grain yield per plant (g). Analysis of variance was carried out following standard procedures to test the significance of genotypic differences. Genotypic and phenotypic coefficients of variation were estimated as per Burton and de Vane (1953) [3] and categorized as low (<10%), moderate (10–20%) and high (>20%). Broad-sense heritability was computed following Lush (1940) [10] and Hanson *et al.* (1956) [5], and categorized as low (<30%), moderate (30–60%) and high (>60%). Genetic advance and genetic advance as a percentage of mean were estimated following Johnson *et al.* (1955) [8]. Genotypic and phenotypic correlation coefficients among all trait pairs were computed as per Al-Jibouri *et al.* (1958) [1].

3. Results and Discussion

3.1 Analysis of variance and mean performance

The analysis of variance revealed highly significant ($p < 0.01$) mean sum of squares due to genotypes for all ten characters studied, confirming the existence of substantial genetic variability among the thirty-four foxtail millet genotypes evaluated. This finding is consistent with the reports of Harish and Lavanya (2022) [7], Zhang *et al.* (2023) [19] and Rao and Chaturvedi (2024)

[14], who similarly recorded highly significant genotypic variation for yield and its component traits in foxtail millet, thereby confirming that the material was suitable for further genetic analysis.

The mean performance of the genotypes for the ten characters studied is presented in Table 1. Days to 50% flowering ranged from 41.67 to 62.33 days (mean 53.52 days) and days to maturity from 74.67 to 99.67 days (mean 86.63 days), with SIFT-10 being the earliest and SIFT-1 the latest genotype for both traits. Plant height varied from 91.71 to 123.99 cm (mean 109.09 cm), productive tillers per plant from 1.76 to 6.17 (mean 3.49), panicle length from 11.50 to 23.50 cm (mean 17.08 cm) and peduncle length from 9.89 to 15.26 cm (mean 12.62 cm). Panicle weight ranged from 3.65 to 20.50 g, straw yield per plant from 29.28 to 54.92 g and test weight from 1.33 to 3.75 g, while grain yield per plant, the character of primary economic interest, showed the widest relative spread (2.50–15.50 g; mean 7.65 g). The genotype SIFT-12 recorded the highest mean values for productive tillers per plant, panicle length, panicle weight, test weight and grain yield per plant, followed closely by BFTM-82-14 and BFTM-82-6, identifying them as the most promising genotypes for direct exploitation or use as parents in hybridization. The wide range recorded for flowering, maturity and yield-related traits agrees with the observations of Ramesh *et al.* (2023) [13] and Rao and Chaturvedi (2024) [14] in foxtail millet germplasm.

Table 1: Mean performance of 34 foxtail millet genotypes for ten quantitative characters

Sr. No.	Genotype	DF (days)	DM (days)	PH (cm)	PT (no.)	PL (cm)	PedL (cm)	PW (g)	SY (g)	TW (g)	GY (g)
1	SIFT-1	62.33	99.67	114.16	3.06	12.78	10.96	11.12	32.98	2.51	6.90
2	SIFT-2	49.33	84.33	112.83	3.31	14.54	14.02	9.67	30.82	2.10	7.17
3	SIFT-3	57.67	95.00	101.24	2.06	13.23	11.62	7.52	30.58	2.09	5.40
4	SIFT-3-1	56.00	86.33	122.04	3.82	17.77	14.50	16.86	38.31	2.33	9.73
5	SIFT-4	48.00	81.00	105.87	2.74	13.60	11.78	9.36	32.28	2.45	5.30
6	SIFT-6-9	57.00	87.67	99.66	3.11	18.80	10.70	12.71	38.50	2.66	9.07
7	SIFT-6-1	54.33	95.67	104.10	1.98	13.90	14.96	4.85	36.85	2.37	3.53
8	SIFT-7	46.33	78.00	104.12	2.79	14.12	13.81	6.12	36.63	2.12	3.93
9	SIFT-8	48.67	78.00	123.99	2.87	13.07	13.57	12.56	33.45	2.84	8.83
10	SIFT-9-1	44.00	83.00	91.71	2.54	12.85	12.18	5.87	30.17	1.33	4.23
11	SIFT-9-2	44.33	76.00	110.32	3.18	14.80	13.87	8.18	29.28	2.53	7.03
12	SIFT-10	41.67	74.67	110.34	4.64	17.85	15.26	12.23	38.66	2.83	10.17
13	SIFT-12	56.33	87.00	123.00	6.17	23.50	12.17	20.50	52.71	3.75	15.50
14	SIFT-13	45.00	80.00	110.72	5.89	18.23	9.89	10.44	37.38	2.70	6.77
15	BFTM-82-2	53.67	87.00	113.85	3.32	16.47	11.65	17.17	38.80	2.78	9.77
16	BFTM-82-5	54.33	85.67	107.83	2.90	16.10	13.84	15.28	39.97	2.61	8.57
17	BFTM-82-6	56.00	86.67	117.72	5.95	22.38	11.56	19.64	39.06	3.62	14.23
18	BFTM-82-7	53.00	88.33	104.36	4.49	17.97	13.12	8.86	42.17	2.81	6.07
19	BFTM-82-9	54.67	87.67	113.03	3.55	21.50	11.92	12.15	38.54	2.85	8.60
20	BFTM-82-10	57.67	89.00	113.55	5.92	22.05	12.21	17.60	33.47	3.10	10.20
21	BFTM-82-14	56.00	84.67	114.36	5.97	23.00	12.68	19.90	41.39	3.68	15.23
22	BFTM-82-28	59.67	89.33	110.73	3.56	18.52	13.07	8.95	54.92	2.69	8.50
23	BFTM-82-40	57.00	85.00	105.41	3.20	21.78	12.65	17.34	39.98	2.79	9.77
24	BFTM-82-58	51.67	84.00	114.82	3.19	19.43	12.73	11.70	44.17	3.06	8.17
25	BFTM-82-62	56.67	89.33	106.75	4.94	18.24	12.11	10.14	41.19	2.43	8.50
26	BFTM-82-65	56.67	87.67	105.71	3.88	17.21	13.91	6.91	39.78	2.18	5.60
27	BFTM-82-69	52.00	91.00	101.71	2.87	16.93	11.27	8.32	40.60	2.33	5.33
28	BFTM-82-79	52.33	84.00	109.70	2.15	16.34	11.74	5.75	41.74	2.12	4.40
29	BFTM-82-80	52.67	91.00	100.25	2.28	16.38	11.10	7.95	39.35	2.28	5.70
30	BFTM-82-81	56.67	95.33	107.25	1.76	11.50	14.24	4.63	33.24	2.13	2.50
31	BFTM-82-86	55.33	86.00	109.48	2.49	16.15	12.05	8.59	41.61	2.53	6.50
32	BFTM-82-87	55.00	91.33	99.51	2.22	16.92	12.89	8.93	43.90	2.14	5.77
33	BFTM-82-88	59.00	87.00	107.55	1.99	14.30	12.64	3.65	42.04	2.58	3.63
34	PDKV Yashashree (Check)	58.67	89.00	111.27	3.73	18.63	12.24	11.82	38.44	2.63	9.47
	SE(m)±	1.46	1.84	4.01	0.29	1.11	0.85	0.90	2.38	0.16	0.53
	General Mean	53.52	86.63	109.09	3.49	17.08	12.62	10.98	38.62	2.59	7.65
	CD at 5%	4.14	5.18	11.33	0.82	3.14	2.39	2.55	6.71	0.46	1.48

DF = Days to 50% flowering, DM = Days to maturity, PH = Plant height, PT = Productive tillers/plant, PL = Panicle length, PedL = Peduncle length, PW = Panicle weight, SY = Straw yield/plant, TW = Test weight, GY = Grain yield/plant.

3.2 Genetic variability, heritability and genetic advance

Estimates of range, mean, genotypic and phenotypic coefficients of variation, heritability and genetic advance are presented in Table 2. For all ten characters, the phenotypic coefficient of variation (PCV) was higher than the corresponding genotypic coefficient of variation (GCV), indicating that environmental factors contributed, along with genetic factors, to the total observed variability — a trend also reported by Ayesha *et al.* (2019) [2], Harish and Lavanya (2022) [7] and Rao and Chaturvedi (2024) [14] in foxtail millet. However, the differences between GCV and PCV were narrow for most yield-contributing traits, suggesting a comparatively limited environmental influence on their expression.

Panicle weight, grain yield per plant and productive tillers per plant recorded high GCV and PCV (>20%), reflecting considerable genetic variability and good scope for improvement through direct selection, in agreement with Ayesha *et al.* (2019) [2], Harish and Lavanya (2022) [7] and Kushwaha *et al.* (2026) [9]. Panicle length, test weight and straw yield per plant exhibited moderate GCV and PCV, while days to 50% flowering, days to maturity, plant height and peduncle length showed low estimates, indicating a comparatively narrow genetic base for these traits

(Rao and Chaturvedi, 2024) [14].

Broad-sense heritability was high (>60%) for grain yield per plant (92.10%), panicle weight (89.48%), productive tillers per plant (86.16%), days to 50% flowering (77.73%), days to maturity (72.96%), test weight (72.32%) and panicle length (70.94%), moderate for straw yield per plant (60.31%) and plant height (40.72%), and low for peduncle length (29.02%). High heritability along with high genetic advance as per cent of mean (GAM) was recorded for panicle weight (81.07%), grain yield per plant (80.31%), productive tillers per plant (68.93%), test weight (31.11%), panicle length (30.59%) and straw yield per plant (21.03%), indicating that additive gene action predominates in the inheritance of these characters and that simple phenotypic selection would be effective for their improvement (Johnson *et al.*, 1955; Ramesh *et al.*, 2023; Rao and Chaturvedi, 2024; Kushwaha *et al.*, 2026) [8, 13, 14, 9]. In contrast, plant height and peduncle length combined low-to-moderate heritability with low GAM, suggesting a greater role of non-additive gene action; improvement of these traits would therefore require biparental mating, heterosis breeding or recurrent selection rather than simple selection in early segregating generations.

Character	Range (Min–Max)	General Mean	GCV (%)	PCV (%)	Heritability (b.s.) %	Genetic Advance (GA)	GA as % of Mean
Days to 50% flowering	41.67 – 62.33	53.52	8.87	10.06	77.73	8.62	16.11
Days to maturity	74.67 – 99.67	86.63	6.03	7.06	72.96	9.19	10.61
Plant height (cm)	91.71 – 123.99	109.09	5.28	8.28	40.72	7.58	6.94
Productive tillers/plant	1.76 – 6.17	3.49	36.05	38.83	86.16	2.40	68.93
Panicle length (cm)	11.50 – 23.50	17.08	17.63	20.93	70.94	5.23	30.59
Peduncle length (cm)	9.89 – 15.26	12.62	7.42	13.77	29.02	1.04	8.23
Panicle weight (g)	3.65 – 20.50	10.98	41.60	43.98	89.48	8.90	81.07
Straw yield/plant (g)	29.28 – 54.92	38.62	13.15	16.93	60.31	8.12	21.03
Test weight (g)	1.33 – 3.75	2.59	17.76	20.88	72.32	0.80	31.11
Grain yield/plant (g)	2.50 – 15.50	7.65	40.62	42.33	92.10	6.14	80.31

*GCV = Genotypic coefficient of variation, PCV = Phenotypic coefficient of variation, GA = Genetic advance

3.3 Correlation studies

Genotypic and phenotypic correlation coefficients among the ten characters studied are presented together in Table 3, with genotypic correlations given above the diagonal and phenotypic correlations below the diagonal. For most trait combinations, genotypic correlation coefficients exceeded the corresponding phenotypic coefficients in magnitude, indicating a strong inherent genetic association between traits that were partly masked at the phenotypic level by environmental effects — a pattern also reported by Harish and Lavanya (2022) [7] and Rao and Chaturvedi (2024) [14] in foxtail millet.

Grain yield per plant exhibited highly significant and positive genotypic correlation with panicle weight (0.949), test weight (0.887), panicle length (0.865), productive tillers per plant (0.812) and plant height (0.789), and a significant positive correlation with straw yield per plant (0.386); the corresponding phenotypic correlations followed the same trend, though of lower magnitude (panicle weight 0.903, test weight 0.758, panicle length 0.690, productive tillers per plant 0.717, plant height 0.461). These results identify panicle weight, test weight, panicle length, productive tillers per plant and plant height as the principal yield-determining characters, in agreement with Harish and Lavanya (2022) [7], who reported panicle length, tillers per plant and test weight as important selection traits, and with Rao and Chaturvedi (2024) [14], who recorded a similar significant positive association of grain yield with panicle length, plant height and biological-

yield-related traits.

Among the component traits, plant height showed highly significant positive association with productive tillers per plant, panicle length, panicle weight and test weight, while panicle weight was in turn strongly and positively correlated with panicle length, productive tillers per plant and test weight, reflecting a close inter-linkage among the panicle- and tiller-related trait complex, as also noted by Ayesha *et al.* (2019) [2] and Kushwaha *et al.* (2026) [9]. Days to 50% flowering showed a highly significant positive genotypic correlation with days to maturity (0.867) and straw yield per plant (0.420), while peduncle length was the only trait to show a consistent, though non-significant to significant negative, association with most other characters, including grain yield per plant, indicating that longer peduncles do not favour yield expression. Days to maturity recorded a significant negative correlation with peduncle length and a negative, non-significant correlation with grain yield per plant, suggesting that late-maturing genotypes tend towards comparatively lower yield.

Overall, the strong positive inter-correlation of panicle weight, panicle length, productive tillers per plant, plant height and test weight with grain yield per plant suggests that simultaneous improvement of these attributes, through direct or indirect selection, would be the most effective strategy for enhancing grain yield in foxtail millet.

Table 3: Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients among yield and yield-component traits in foxtail millet

Character	DF	DM	PH	PT	PL	PedL	PW	SY	TW	GY
DF	1.000	0.867**	0.178	0.007	0.269	-0.301	0.220	0.420*	0.256	0.192
DM	0.651**	1.000	-0.180	-0.229	-0.097	-0.368*	-0.138	0.111	-0.118	-0.200
PH	0.113	-0.214	1.000	0.519**	0.476**	0.449**	0.795**	0.271	0.758**	0.789**
PT	0.006	-0.223	0.476**	1.000	0.838**	-0.183	0.746**	0.300	0.744**	0.812**
PL	0.233	-0.078	0.244	0.633**	1.000	-0.241	0.820**	0.629**	0.859**	0.865**
PedL	-0.124	-0.096	-0.073	-0.142	-0.200	1.000	-0.268	-0.070	-0.114	-0.134
PW	0.177	-0.105	0.405*	0.621**	0.620**	-0.003	1.000	0.248	0.842**	0.949**
SY	0.294	0.091	0.118	0.211	0.457**	-0.044	0.199	1.000	0.507**	0.386*
TW	0.216	-0.125	0.574**	0.676**	0.617**	-0.141	0.652**	0.355*	1.000	0.887**
GY	0.178	-0.151	0.461**	0.717**	0.690**	-0.075	0.903**	0.307	0.758**	1.000

* Significant at 5% level, ** Significant at 1% level.

DF = Days to 50% flowering; DM = Days to maturity; PH = Plant height; PT = Productive tillers/plant; PL = Panicle length; PedL = Peduncle length; PW = Panicle weight; SY = Straw yield/plant; TW = Test weight; GY = Grain yield/plant.

4. Conclusion

The present investigation confirmed the existence of significant genotypic variability among the thirty-four foxtail millet genotypes for all ten characters studied. The consistently higher phenotypic than genotypic coefficient of variation indicated a moderate influence of environment, but panicle weight, grain yield per plant, productive tillers per plant, panicle length, test weight and straw yield per plant combined high heritability with high genetic advance as per cent of mean, pointing to the predominance of additive gene action and confirming that these traits can be reliably improved through simple phenotypic selection. Genotypic correlation coefficients were generally higher than phenotypic correlations, and grain yield per plant showed strong, significant positive association with panicle weight, test weight, panicle length, productive tillers per plant, plant height and straw yield per plant, establishing these as the most dependable component traits for indirect selection. Based on mean performance, the genotypes SIFT-12, BFTM-82-14 and BFTM-82-6 emerged as the most promising for grain yield per plant and may be considered valuable parental material for future foxtail millet improvement programmes. Overall, selection emphasizing panicle weight, productive tillers per plant, panicle length, test weight and plant height, either directly or through multiple-trait selection indices, is recommended for the genetic enhancement of grain yield in foxtail millet.

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