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CN Shinde
PG Scholar, Department of Genetics and Plant Breeding, RCSM College of Agriculture, Kolhapur, Maharashtra, India

MS Kamble
Assistant Professor of Agricultural Botany, RCSM College of Agriculture, Kolhapur, Maharashtra, India

YG Ban
Junior Breeder, AICRP on Small Millets Zonal Agricultural Research Station, Kolhapur, Maharashtra, India

MS Mote
Associate Professor of Agricultural Botany, RCSM College of Agriculture, Kolhapur, Maharashtra, India

PN Gajbhiye
Assistant Professor of Soil Science and Agril. Chemistry, Zonal Agricultural Research Station, Kolhapur, Maharashtra, India

RS Dhumal
PG Scholar, Department of Genetics and Plant Breeding, RCSM College of Agriculture, Kolhapur, Maharashtra, India

RH Gound
PG Scholar, Department of Genetics and Plant Breeding, RCSM College of Agriculture, Kolhapur, Maharashtra, India

Corresponding Author:
CN Shinde
PG Scholar, Department of Genetics and Plant Breeding, RCSM College of Agriculture, Kolhapur, Maharashtra, India

Genetic variability studies in barnyard millet (*Echinochloa frumentacea*)

CN Shinde, MS Kamble, YG Ban, MS Mote, PN Gajbhiye, RS Dhumal and RH Gound

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Abstract
Barnyard millet is well suited for sustainable agriculture due to its adaptability to low-input conditions, photo-insensitivity and tolerance to abiotic stresses, making it particularly valuable in non-irrigated and marginal areas. Nutritionally, it surpasses many major cereals, being richer in proteins, fiber, vitamins and minerals.

In the present study, thirty-three barnyard millet genotypes along with two checks, *Phule Barti-1* and *DHBM-93-03*, were evaluated for yield and its contributing traits to assess genetic variability. The analysis of variance revealed highly significant differences among the genotypes, indicating substantial genetic variability. For all traits, phenotypic coefficient of variation (PCV) values exceeded genotypic coefficient of variation (GCV), suggesting environmental influence on trait expression. Traits such as flag leaf blade length, flag leaf blade width and plant height showed moderate PCV and GCV, indicating their potential utility in selection. Peduncle length exhibited high heritability, while plant height recorded the highest genetic advance. Furthermore, 1000-grain weight showed the highest genetic advance expressed as a percentage of the mean.

Keywords: Barnyard millet, GCV, PCV, heritability, genetic advance.

Introduction
Barnyard millet (*Echinochloa frumentacea*) is one of the earliest domesticated small millets, thought to have originated around 3000-4000 years ago in the semi-arid tropical regions of Asia and Africa. In India, barnyard millet is widely cultivated on hilly slopes and in tribal belts of Odisha, Madhya Pradesh, Uttarakhand, Tamil Nadu, Andhra Pradesh, Maharashtra and Bihar, making India the leading country globally in terms of barnyard millet area and production (Arya *et al*., 2018) [3]. Obara (1938) [14] first reported the wide morphological variation in flowering time, plant height, and panicle traits in barnyard millet, highlighting its potential for genetic improvement. Napper (1965) [11] described the panicle structure, which varies in shape *viz*. cylindrical, pyramidal or globose with spikelets that may be awned or awnless. Later, Yabuno (1971) [29] and De Wet *et al*. (1983) [6] differentiated two cultivated species, *E. frumentacea* and *E. esculenta*, based on spikelet and glume texture and classified them into distinct races according to inflorescence morphology. It is an annual, fast-growing, and hardy crop that typically grows to a height of 60-120 cm and matures within 45-60 days, allowing harvest within nine weeks (Muldoon *et al*., 1982) [10]. It has a tetraploid chromosome number (2n = 4x = 36) and produces a panicle capable of yielding a high number of seeds, with 1000-kernel weight ranging from 2-4 g. The genus *Echinochloa* includes around 250 species distributed across tropical and temperate regions (Bajwa *et al*., 2015) [4]. The crop contains approximately protein (12%) and fibre (13%), along with moderate levels of minerals such as calcium (25 mg/100 g) and iron (Veena, 2013) [26], making it nutritionally valuable. Barnyard millet thrives in a range of soil types, growing well in well-drained loamy to sandy loam soils with a pH of 5.5-8.5 and demonstrates resilience even in marginal and hilly soils (Seetharam, 1998; Yabuno, 1987) [20, 29]. Its adaptability to low-input conditions, photo-insensitivity and resistance to abiotic stresses make it an ideal crop for sustainable agriculture, especially in non-irrigated and marginal lands where rice and other cereals often fail due to poor soil quality or limited water availability

(Muldoon *et al*., 1982; Seetharam, 1998) [10, 20]. For optimal growth, deep, loamy, fertile soils with high organic matter content are preferred. Despite its potential, systematic breeding efforts in barnyard millet have largely been overlooked (Subramanian *et al*., 2010) [22]. To initiate effective crop improvement programs, knowledge of the genetic diversity, disease resistance, and nutritional content within the population is essential. Evaluating the variability in yield-related traits using parameters such as phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability, and genetic advance can provide effective selection criteria for crop improvement.

Material and Methods

The experimental material consisted of 35 barnyard millet genotypes along with two checks, *Phule Barti-1* and *DHBM-9303*, as detailed in Table 1. These genotypes were procured from the AICRP on Small Millets, Zonal Agricultural Research Station, Shenda Park, Kolhapur (MS). The field evaluation was carried out at the RSJRS, Kolhapur Centre during the summer of 2024. The experiment was laid out in a randomized block design with three replications. Analysis of variance for each trait was performed following the procedure outlined by Panse and Sukhatme (1985) [15]. Estimates of broad-sense heritability, phenotypic and genotypic coefficients of variation were computed using the method of Burton and Devane (1952) [5]. Genetic advance and genetic advance as a percentage of mean were derived according to the procedure suggested by Johnson *et al*. (1955) [8].

Results and Discussion

The results of the analysis of variance for various quantitative characters for thirty-five genotypes of barnyard millet is presented in the Table 2. The results indicated that there is highly significant differences among genotypes for all the characters *viz*., days to 50 per cent flowering, days to physiological maturity, plant height (cm), panicle length (cm), peduncle length (cm), flag leaf blade length (cm), flag leaf blade width (cm), basal tiller number, test weight (g) and grain yield per plant (g) demonstrated that there is sufficient variation for future development. Mean performance of genotypes for these characters is presented in Table 3.

(A) GCV and PCV

Parameters of genetic variability *viz*., genotypic coefficient of variation, phenotypic coefficient of variation, heritability in broad sense, genetic advance and genetic advance as per cent of mean were estimated for yield and yield attributing traits. All the 10 characters studied are presented in the Table 4. The PCV values were higher than the GCV values for all the characters. This showed that, the environment is having a masking effect on the manifestation of genetic diversity of all the characters under study. The traits such as flag leaf blade length (10.11, 10.79), flag leaf blade width (10.48, 11.2), plant height (11.62, 12.15), peduncle length (16.08, 16.48), days to 50 per cent flowering (16.09, 16.54), grain yield per plant (17.27, 17.79) and 1000 grain weight (18.31, 18.77) estimated moderate GCV and also PCV (10.1 to 20) revealed less room for improvement under direct selection for these traits due to reduced variation.

Vikram *et al*. (2020) [28] and Nireekshitha M.K. *et al*. (2025) [13] reported moderate PCV and GCV for traits like flag leaf blade length and width, days to 50 per cent flowering, days to maturity and 1000 grain weight. Ranjana *et al*. (2020) [17] observed low GCV (7.75%) and moderate PCV (10.28%) for basal tiller number, indicating environmental influence and moderate variability for flag leaf width. Rakesh *et al*. (2015) [16] found moderate GCV and PCV for plant height, 1000 grain weight and grain yield in *Pennisetum glaucum*. The traits panicle length (7.62, 8.47) and days to physiological maturity (7.97, 8.73) exhibited low GCV and PCV values (below 10 percent), indicating limited genetic variability among the genotypes for these traits. Anuradha *et al*. (2020) [1] reported low PCV and GCV values for panicle length and days to physiological maturity, supporting the present findings.

Genetic variability parameters GCV, PCV, heritability (broad sense), genetic advance, and genetic advance as per cent of mean were estimated for 10 yield and yield-attributing traits (Table 4). In all traits, PCV values were higher than GCV values, indicating the influence of environment on trait expression.

Moderate GCV and PCV values were recorded for flag leaf blade length (10.11%, 10.79%), flag leaf blade width (10.48%, 11.20%), plant height (11.62%, 12.15%), peduncle length (16.08%, 16.48%), days to 50 per cent flowering (16.09%, 16.54%), grain yield per plant (17.27%, 17.79%) and 1000 grain weight (18.31%, 18.77%), indicating moderate variability and reduced scope for improvement through direct selection.

Vikram *et al*. (2020) [28] and Nireekshitha M.K. *et al*. (2025) [13] also reported moderate PCV and GCV for the traits like flag leaf blade length and width, days to 50 per cent flowering, days to maturity, and 1000 grain weight. Ranjana *et al*. (2020) [17] observed low GCV (7.75%) and moderate PCV (10.28%) for basal tiller number and moderate variability for flag leaf width. Rakesh *et al*. (2015) [16] reported moderate GCV and PCV for plant height, 1000 grain weight and grain yield in *Pennisetum glaucum*.

Low GCV and PCV values were noted for panicle length (7.62%, 8.47%) and days to physiological maturity (7.97%, 8.73%), indicating limited genetic variability. Similar results were observed by Anuradha *et al*. (2020) [1] and Vanniarajan and Chandirakala (2020) [25].

(B) Heritability

Broad-sense heritability estimates ranged from 65.4 to 95.3 per cent. The highest heritability was recorded for peduncle length (95.3%), followed by 1000 grain weight (95.1%), days to 50 per cent flowering (94.6%), grain yield per plant (94.2%), plant height (91.5%), flag leaf blade length (87.8%), flag leaf blade width (87.6%), days to physiological maturity (83.2%) and panicle length (80.9%). These high values indicate that genetic factors contributed significantly to phenotypic variance for these traits.

Basal tiller number was the only trait that exhibited moderate heritability (65.4%), suggesting a greater influence of environmental factors on its expression.

These findings align with those of Sood *et al*. (2015) [21] for traits like plant height, flag leaf blade width and length and grain yield per plant. Similar trends were reported by Vetriventhan and Upadhyaya (2018) [27] in proso millet and by Vanniarajan and Chandirakala (2020) [25] and Renganathan *et al*. (2018) [18] in barnyard millet for traits such as days to 50 per cent flowering, days to maturity, plant height, flag leaf traits, panicle length, 1000 grain weight and grain yield.

(C) Genetic Advance

The highest genetic advance was observed for plant height (26.72), followed by days to 50 per cent flowering (16.25), days to physiological maturity (13.52), peduncle length (5.49) and

flag leaf blade length (4.17), indicating that selection for these traits can lead to significant improvement in future hybridization programs.

Lower genetic gains were recorded for grain yield per plant (2.70), panicle length (2.56), 1000 grain weight (0.95), basal tiller number (0.74) and flag leaf blade width (0.50), suggesting limited scope for improvement through direct selection.

These results are in agreement with Anuradha *et al*. (2020) [1], who reported low genetic advance for panicle length in barnyard millet. Kavya *et al*. (2017) [9] also observed low genetic advance for basal tiller number, flag leaf blade length and width, peduncle length, panicle length and 1000 grain weight with moderate values for days to 50 per cent flowering and high values for plant height, supporting the present findings. Similar observations were reported by Sarak *et al*. (2023) [19] and Tejaswini *et al*. (2014) [23] in little millet, and by Tyagi *et al*. (2011) [24] in foxtail millet for the traits like plant height, grain yield, and flag leaf characteristics. Corresponding results were also reported by Nireekshitha M.K. *et al*. (2025) [13] in Kodo millet for traits such as days to 50 per cent flowering, plant height, panicle length, flag leaf traits, 1000 grain weight and basal tiller number.

(D) Genetic advance as per cent of mean

High genetic advance as a per cent of mean was recorded for 1000 grain weight (36.78%), grain yield per plant (34.52%), peduncle length (32.34%), days to 50 per cent flowering (32.23%), plant height (22.91%) and flag leaf blade width (20.21%), indicating the predominance of additive gene action and suggesting that selection would be effective for improving these traits.

Moderate genetic advance as per cent of mean was observed for flag leaf blade length (19.52%), basal tiller number (15.44%), days to physiological maturity (14.98%) and panicle length (14.12%), indicating the influence of non-additive gene action.

These findings are consistent with those of Arunachalam *et al*. (2012) [2] and Sood *et al*. (2015) [21] in barnyard millet for traits like plant height and days to physiological maturity. Similar results were reported by Deepak *et al*. (2023) [7] for traits such as days to 50 per cent flowering, plant height, flag leaf traits, panicle length, 1000 grain weight and grain yield per plant. Nehru *et al*. (2021) [12] also reported comparable findings for days to 50 per cent flowering, days to physiological maturity, 1000 grain weight, peduncle length and grain yield per plant.

Table 1: List of barnyard millet genotypes included in the study:

Sr. No.	Genotypes	Sr. No.	Genotypes
1.	KOPBM-23-03	19.	KOPBM-23-35
2.	KOPBM-23-05	20.	KOPBM-23-36
3.	KOPBM-23-06	21.	KOPBM-23-37
4.	KOPBM-23-07	22.	KOPBM-23-38
5.	KOPBM-23-10	23.	KOPBM-23-39
6.	KOPBM-23-11	24.	KOPBM-23-40
7.	KOPBM-23-12	25.	KOPBM-23-42
8.	KOPBM-23-14	26.	KOPBM-23-43
9.	KOPBM-23-18	27.	KOPBM-23-44
10.	KOPBM-23-19	28.	KOPBM-23-45
11.	KOPBM-23-22	29.	KOPBM-23-46
12.	KOPBM-23-24	30.	KOPBM-23-47
13.	KOPBM-23-25	31.	KOPBM-23-48
14.	KOPBM-23-26	32.	KOPBM-23-49
15.	KOPBM-23-28	33.	KOPBM-23-50
16.	KOPBM-23-29	34	Phule barti-1 (C)
17.	KOPBM-23-31	35	DHBM-93-03 (C)
18.	KOPBM-23-34		

Table 2: Analysis of variance for ten characters in barnyard millet

Sr. No.	Character	Mean sum of square (MSS)		
		Replication df = 2	Treatment df = 34	Error df= 68
1	Days to 50 per cent flowering	2.78	208.63**	11.30
2	Days to physiological maturity	2.47	186.72**	31.36
3	Plant height (cm)	14.66	602.60**	51.09
4	Panicle length (cm)	0.04	7.10**	1.35
5	Peduncle length (cm)	0.54	23.49**	1.11
6	Flag leaf blade length (cm)	0.007	15.93**	1.93
7	Flag leaf blade width (cm)	0.012	0.23**	0.03
8	Basal tiller number	0.07	0.90**	0.31
9	1000 grain weight (g)	0.002	0.71**	0.03
10	Grain yield per plant (g)	0.06	5.77**	0.34

*, ** significant at 5 and 1 per cent, respectively.

Table 3: Mean performance of 35 genotypes of barnyard millet for twelve characters.

Sr. No	Genotypes	Days to 50 per cent flowering	Days to physiological maturity	Plant height (cm)	Panicle length (cm)	Peduncle length (cm)	Flag leaf blade length (cm)	Flag leaf blade width (cm)	Basal tiller number	1000 grain weight (g)	Grain yield per plant (g)
1	KOPBM-23-03	45	85	110.03	17.93	14.63	17.13	2.35	5.00	1.90	7.00
2	KOPBM-23-05	59	83	133.87	14.87	13.00	19.27	2.77	4.33	2.43	5.17
3	KOPBM-23-06	52	84	117.57	16.33	14.30	22.47	2.49	4.67	2.17	6.23
4	KOPBM-23-07	45	86	107.57	17.80	15.00	21.53	2.13	4.67	1.77	7.40
5	KOPBM-23-10	41	97	93.40	17.80	19.97	23.73	1.97	5.00	3.07	8.77
6	KOPBM-23-11	43	91	100.27	16.73	17.77	23.27	2.43	6.00	2.77	8.50
7	KOPBM-23-12	46	86	113.80	16.87	17.97	22.40	2.46	4.67	2.57	6.63
8	KOPBM-23-14	44	84	106.33	19.20	14.50	23.13	2.26	5.67	2.50	6.77
9	KOPBM-23-18	46	86	112.27	19.47	15.67	23.93	2.44	5.33	2.27	6.67
10	KOPBM-23-19	45	85	109.20	20.20	14.87	19.20	2.31	4.67	3.03	6.97
11	KOPBM-23-22	43	83	103.17	14.27	14.40	20.40	2.25	5.67	1.90	6.70
12	KOPBM-23-24	45	86	110.6	18.73	12.90	20.07	2.36	3.33	2.53	7.43
13	KOPBM-23-25	45	85	121.80	18.93	13.83	20.33	2.33	4.33	2.23	7.33
14	KOPBM-23-26	58	97	108.93	18.27	21.60	21.67	2.83	5.00	3.03	8.83
15	KOPBM-23-28	53	92	92.20	19.40	15.15	23.27	3.01	4.33	3.30	9.10
16	KOPBM-23-29	56	96	109.73	19.20	13.97	25.20	2.64	5.00	2.90	8.23
17	KOPBM-23-31	42	83	127.60	17.80	21.10	17.27	2.30	4.67	2.20	7.17
18	KOPBM-23-34	69	106	142.80	17.33	17.87	19.27	1.84	5.00	1.70	5.17
19	KOPBM-23-35	57	95	98.13	19.40	17.90	20.27	2.22	3.67	1.77	6.50
20	KOPBM-23-36	69	107	119.50	16.33	19.87	19.47	2.58	4.33	2.83	8.57
21	KOPBM-23-37	54	94	123.90	16.73	17.90	24.93	2.67	4.67	1.87	9.07
22	KOPBM-23-38	45	85	98.13	18.13	18.37	20.27	2.23	4.67	3.13	5.93
23	KOPBM-23-39	41	79	138.83	17.53	15.00	25.33	2.89	4.33	3.30	9.07
24	KOPBM-23-40	42	83	126.70	20.87	18.70	19.67	2.74	5.00	2.97	8.70
25	KOPBM-23-42	47	88	116.27	16.60	21.60	18.27	2.49	4.33	2.67	7.97
26	KOPBM-23-43	53	93	119.80	20.93	17.07	20.53	2.59	4.33	2.87	8.40
27	KOPBM-23-44	45	84	106.63	16.73	14.60	22.20	2.28	4.33	2.07	7.13
28	KOPBM-23-45	61	101	137.23	18.67	20.27	22.73	2.87	5.00	3.20	8.93
29	KOPBM-23-46	50	89	122.50	18.67	14.63	20.60	2.56	5.00	2.73	8.03
30	KOPBM-23-47	55	95	116.50	17.73	14.40	19.27	2.65	5.33	2.87	7.90
31	KOPBM-23-48	71	111	153.50	18.07	23.40	26.53	3.05	5.33	3.30	12.53
32	KOPBM-23-49	60	101	136.30	20.33	20.90	20.53	2.87	5.33	3.10	9.30
33	KOPBM-23-50	46	86	115.57	18.33	16.70	19.27	2.48	4.33	2.6	8.20
34	Phule barti-1(C)	47	86	115.87	19.27	16.73	22.73	2.48	5.33	2.67	7.93
35	DHBM-93-03(C)	48	88	116.27	19.67	17.77	21.60	2.49	4.67	2.70	8.67
	Mean	50	90	116.65	18.15	16.98	21.36	2.50	4.78	2.60	7.80
	Range	41-71	79-111	92.20-153.50	14.27-20.93	12.90-23.40	17.13-26.53	1.84-3.05	3.33-6.00	1.70-3.30	5.17-12.53
	S.E. ±	1.94	3.23	4.13	0.67	0.61	0.80	0.10	0.32	0.11	0.33
	C.V. (%)	6.67	6.2	6.13	6.41	6.21	6.51	6.85	11.68	7.18	7.42
	CD @ 5%	5.48	9.12	11.65	1.90	1.72	2.27	0.28	0.91	0.30	0.94

Table 4: Parameters of genetic variability of twelve characters in 35 genotypes of barnyard millet.

Sr. No.	Character	Mean	Range	GCV	PCV	Heritability % (b.s)	Genetic advance	G.A. as percent of mean
1	Days to 50 per cent flowering	50.00	41.00 -71.00	16.09	16.54	94.60	16.25	32.23
2	Days to physiological maturity	90.00	79.00 -111.00	7.97	8.73	83.20	13.52	14.98
3	Plant height (cm)	116.65	92.20 -153.50	11.62	12.15	91.50	26.72	22.91
4	Panicle length (cm)	18.15	14.27 -20.93	7.62	8.47	80.90	2.56	14.12
5	Peduncle length (cm)	16.98	12.90 -23.40	16.08	16.48	95.30	5.49	32.34
6	Flag leaf blade length (cm)	21.36	17.13-26.53	10.11	10.79	87.80	4.17	19.52
7	Flag leaf blade width (cm)	2.50	1.84 -3.05	10.48	11.20	87.60	0.50	20.21
8	Basal tiller number	4.78	3.00 -33-60	9.27	11.46	65.40	0.74	15.44
9	1000 grain weight (g)	2.60	1.70 -3.30	18.31	18.77	95.10	0.95	36.78
10	Grain yield per plant (g)	7.80	5.17 -12.53	17.27	17.79	94.20	2.70	34.52

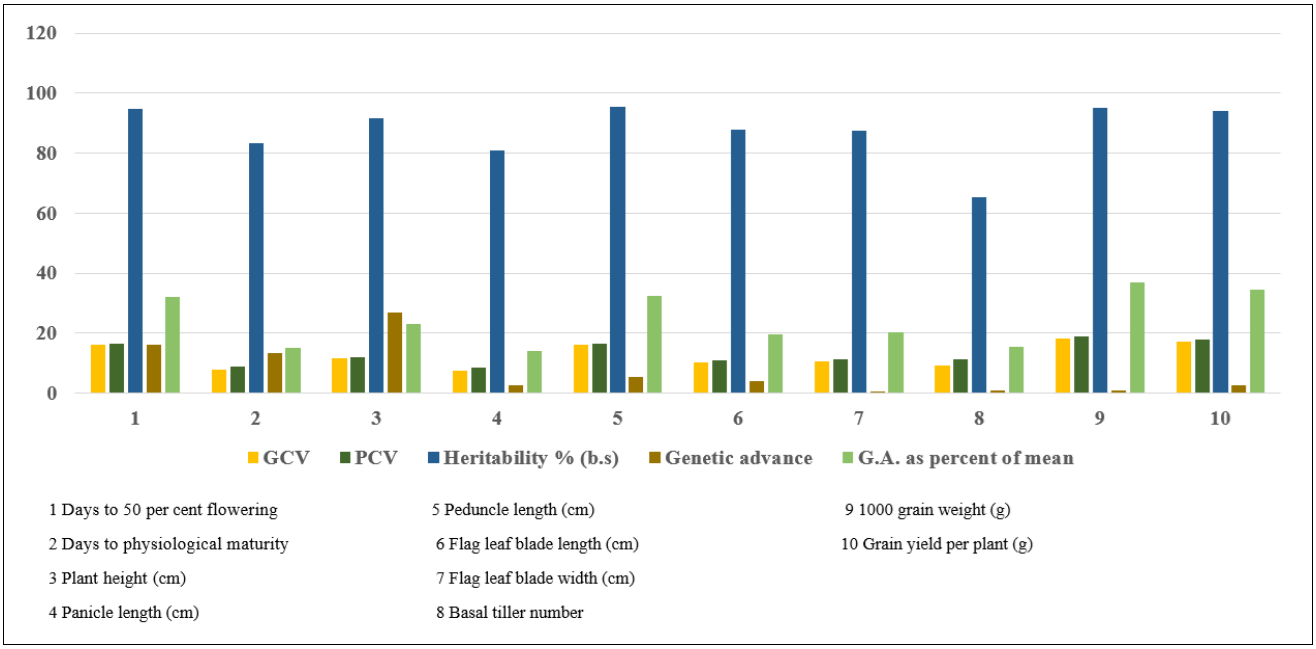

Fig 1: Genetic variability parameters for 10 characters in 35 genotypes of barnyard millet

Conclusions

In the present investigation, several traits exhibited large mean sum of squares, reflecting a considerable extent of genetic variability. For all the studied characters, the phenotypic coefficient of variation (PCV) exceeded the genotypic coefficient of variation (GCV), suggesting environmental influence on trait expression. Traits such as flag leaf blade length, flag leaf blade width, and plant height recorded moderate values for both GCV and PCV, indicating their scope for selection. Peduncle length showed high heritability, while the maximum genetic advance was noted for plant height. The highest genetic advance as a percentage of the mean was observed for 1000-grain weight.

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