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Study of Genetic Variability, Heritability and Genetic Advance in Maize (*Zea mays* L.) Inbred lines

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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 present experiment was conducted to study genetic parameters for ten traits *viz.,* days to 50% anthesis and days to 50% silking, plant height, ear height, ear length, ear girth, kernel rows, kernels per row, 100 grain weight and total grain yield per hectare during kharif and rabi seasons of 2023-24. Using an Alpha Lattice Design, 150 inbred lines were planted in two replications. Analysis of variance revealed significant differences across all traits with phenotypic coefficients of variation (PCV) generally higher than genotypic coefficients of variation (GCV). The highest PCV and GCV were observed for ear height (kharif: 27.59, 23.48; rabi: 25.03, 20.94) and total grain yield (kharif:

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51.26, 47.60; rabi: 38.85, 38.65). Broad-sense heritability was highest for total grain yield (Kharif-86.34, rabi-88.97) in the both seasons. The high heritability of these traits indicates their potential for successful transmission to offspring, enabling efficient selection. High heritability combined with high genetic advance was observed for ear height and total grain yield in both seasons, suggesting these traits as promising targets for improvement through selection driven by additive genetic factors.

Keywords: Heritability; variability; maize; yield.

1. INTRODUCTION

“Maize (*Zea mays* L.) is one of the most versatile emerging crops with wide range adaptability for diverse agro-climatic conditions. Globally, maize is known as the "queen of cereals" due to its highest genetic yield potential among cereals. It is widely used for feed and starch-making, and is grown in at least 171 countries across the globe on an area of 201.98 Mha. Among major crops, it has the highest global production of 1162 Mt, with average productivity of 5755 kg/ha” [1]. “In India, Maize ranks as the third most important cereal crop, followed by rice and wheat, and contributes approximately 10% to the total food grain production in the country. India was the fifth largest producer of maize globally, with a share of 2.59% in world production” [2]. “It is the primary energy source and a major staple food crop for humans, and feed and fodder crop for livestock, in many countries across Africa, Latin America and Asia, including India. Apart from food, feed and fodder-based industries, it also has multi-faceted uses as raw material in industries such as biofuel and starch. Thus, it occupies a prominent position in global agriculture and trade” Yathish et al. [3].

“Heterosis largely depends on the genetic divergence between the parental lines, and selecting genetically diverse parents can be achieved using biometrical methods. In maize breeding programs, the primary goal is to enhance economically important traits while preserving a sufficient level of variability” [4]. To increase the genetic diversity of germplasm, understanding the existing genetic variability within the material is crucial. Genetic variability, which represents heritable differences among genotypes or cultivars, is essential for the success of a long-term breeding program. Zhang et al. [5] demonstrated “the importance of quantifying genetic variability among maize cultivars grown in an area before initiation of breeding programme. Genetic variability is essential for systematically enhancing such complex traits, which can be assessed through phenotypic and genotypic coefficients of variation”. Keeping this in view, the present study was conducted to determine the genetic variability, heritability and genetic advance in maize inbred lines which is of great importance for the plant breeders to initiate the breeding programme.

2. MATERIALS AND METHODS

The present study was undertaken at Winter Nursery Centre, ICAR- Indian Institute of Maize Research, Rajendra Nagar, Hyderabad during kharif and rabi seasons of 2023-24. The experimental material consists of 150 maize inbred lines and these were sown in two replications with Alpha Lattice Design. Each genotype was planted in a single row, 3 meters’ length in each replication, with a spacing of 60 cm between rows and 20 cm within rows. The crop was cultivated with the recommended agricultural practices.

Observations were recorded for ten quantitative traits *viz.,* Days to 50 percent tasseling, Days to 50 percent silking, Plant height (cm), Ear placement height (cm), ear length (cm), ear girth (cm), Number of kernel rows per cob, Number of kernels per row, Grain yield per hectare (kg/ha), and 100-grain weight (grams).

Heritability in the broad sense ($h^2{}_{bs}$) and genetic advance were calculated using the formula provided by Johnson et al. [6]. The genotypic and phenotypic coefficients of variation were determined according to the methods of Burton [7]. The estimates of PCV and GCV were categorized as low (0-10%), moderate (10-20%), and high (>20%) based on the classification by Sivasubramanian and Madhavamenon [8]. The analysis was done using R 4.4.1-win software

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3. RESULTS AND DISCUSSION

3.1 Analysis of Variance

The analysis of variance revealed significant differences among the genotypes for all the traits *viz.,* days to 50% anthesis and days to 50% silking, plant height, ear height, ear length, ear girth, kernel rows, kernels per row, 100 grain weight and total grain yield per hectare in both seasons (Table 1), indicating the presence of genotypic variation among the evaluated genotypes. There is an opportunity to select desirable genotypes with enhanced yield component traits, which may perform well and result in increased yield. These findings are in consistent with the results of previous researchers such as Chandel et al [9], Sinha and Thakur [10], Meena et al. [11].

3.2 Variability and Heritability

The variability of ten quantitative traits in 150 maize inbred lines was assessed using phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability and genetic advance as a percentage of the mean (Table 2).

In this study, the Phenotypic Coefficient of Variation (PCV) was higher than the Genotypic Coefficient of Variation (GCV) for most of the quantitative traits (Table 2) in both the kharif and rabi seasons of 2023-24. Specifically, the difference between PCV and GCV was more pronounced for ear length, kernels per row, and test weight in kharif 2023, and for plant height, ear height, ear length, and kernels per row in rabi 2023-24. This suggests that environmental factors had a greater impact on the phenotypic expression of these traits compared to others.

The highest phenotypic and genotypic coefficients of variation (PCV and GCV) were observed for ear height (kharif: 27.59, 23.48; rabi: 25.03, 20.94) and total grain yield (kharif: 51.26, 47.60; rabi: 38.85, 38.65), which indicates the presence of genetic variability in the studied material. High PCV and GCV values for grain yield and ear height in maize were also reported by Singh et al. [12], Abirami et al. [13], and Bharathi et al. [14]

Moderate GCV and PCV values were observed for the traits of plant height (GCV: kharif-12.39, rabi-12.05; PCV: kharif-15.31, rabi-16.11), which align with similar findings reported by Pradhan et al. [15]. The traits of ear length (GCV: kharif-12.43, rabi-10.93; PCV: kharif-18.06, rabi-17.49) and kernel rows per ear (GCV: kharif-10.37, rabi-10.16; PCV: kharif-14.00, rabi-14.04) also exhibited moderate GCV and PCV values in both seasons. These results are consistent with the experimental findings of Barathi et al. [14].

Low GCV and PCV were observed for the traits of days to 50% anthesis (GCV: kharif-5.83, rabi-4.66; PCV: kharif-7.00, rabi-5.81) and days to 50% silking (GCV: kharif-5.38, rabi-4.2; PCV: kharif-7.18, rabi-5.57) in both seasons. The minimal difference between genotypic and phenotypic coefficients of variation suggests that environmental factors had little effect on the expression of these traits. These findings are consistent with the experimental results of Barathi et al. [14] and Ellandula et al. [16].

Higher broad-sense heritability of traits indicates that a larger proportion of their variation is passed on to offspring. In our study, broad-sense heritability showed the highest values for total grain yield (kharif-86.34, rabi-88.97), followed by ear height (kharif-72.43, rabi-69.98) and Days to 50% anthesis (kharif-69.4, rabi-64) in the both seasons. Additionally, plant height (65.44) in the kharif season and test weight (65.18) in rabi also showing the high heritability. The traits exhibited high heritability in this study, indicated the minimal environmental influence and suggesting that phenotypic selection would be effective for their improvement. Higher heritability indicates the presence of additive gene action, making selection effective in early generations. Similar findings have been reported by Vashistha et al. [17] for traits such as 100 grain weight, days to silking, cob length, plant height, and ear height in maize. Magar et al. [18] also reported high heritability for grain yield per plant and 100 grain weight, consistent with our findings. Rafiq et al. [19] similarly found high heritability for plant height, ear height, grain yield per plant, grains per row, ear length, and 100 grain weight. Ellandula et al. [17], who also reported high heritability for ear height, days to 50% anthesis, and test weight which were aligned with our results.

Moderate heritability was observed for days to 50% silking (kharif-56.21, rabi-56.94) in both seasons which aligns with findings reported by Ellandula et al. [16] and Gokulakrishnan et al. [20]. Similarly moderate heritability was observed for ear length (kharif-47.42 rabi-39.09) in both seasons which were consistent with the experimental findings of Thakur et al. [21]. Moderate heritability for Kernel rows (kharif-54.85, rabi-52.39), and kernels per row (kharif-56.61, rabi-51.43) in both kharif and rabi seasons showed results similar to those reported by

Table 1. Analysis of variance for yield and yield-contributing traits in maize

S. No.	Character/trait	Mean sum of squares							
		Replication (Df:1)		Genotypes (Df:149)		Blocks (Df:14)		Error (Df:135)	
		Kharif 2023	Rabi 2023-24	Kharif 2023	Rabi 2023-24	Kharif 2023	Rabi 2023-24	Kharif 2023	Rabi 2023-24
1	Days to 50 per cent Anthesis	38.88	6.45	30.80**	28.80**	4.20	7.18	5.70	6.27
2	Days to 50 per cent silking	19.76	29.45	31.85**	26.70**	5.10	4.48	9.32	7.32
3	Plant height (cm)	82.16	122.24	616.9**	611.77**	136.81	210.63	128.07	172.90
4	Ear placement height (cm)	1.37	17.76	223.94**	197.72**	50.88	40.11	34.21	34.92
5	Ear length (cm)	6.39	3.91	5.88**	5.44**	2.35	1.99	2.07	2.38
6	Ear girth (cm)	2.67	0.05	0.27**	0.2**	0.165	0.07	0.11	0.08
7	Kernel rows Per Ear	0.17	2.08	4.19**	4.00**	0.86	1.33	1.26	1.24
8	Number of Kernel Per Row	19.25	8.67	29.00**	26.02**	8.82	5.23	7.95	8.34
9	100 grain weight (g)	73.01	8.33	26.16**	24.85**	9.58	6.21	9.60	5.16
10	Total Grain yield Per Hectare	27343	46995	525865**	347401**	52156	15339	37130	20273

*** Significant at 1% level* **Significant at 5%* level

Table 2. Genetic variability parameters for yield and yield-contributing traits in maize

S. No.	Character	Mean		Range				Coefficient of Variation				Heritability (broad sense) h^2(bs) (%)		GAM	
				Minimum		Maximum		PCV (%)		GCV (%)					
		K	R	K	R	K	R	K	R	K	R	K	R	K	R
1	DA	60.88	72.00	50.00	59.00	75.00	80.00	7.00	5.81	5.83	4.66	69.40	64.00	9.98	7.69
2	DS	62.88	73.97	51.00	59.00	76.00	82.00	7.18	5.57	5.38	4.20	56.21	56.94	8.31	6.50
3	PH	126.06	122.92	62.00	182.00	192.66	73.00	15.31	16.11	12.39	12.05	65.44	55.93	20.64	18.56
4	EH	41.29	43.08	15.00	19.00	72.66	78.00	27.59	25.03	23.48	20.94	72.43	69.98	41.17	36.08
5	EL	11.06	11.31	5.66	6.60	16.50	18.06	18.06	17.49	12.43	10.93	47.42	39.09	17.64	14.08
6	EG	2.63	2.81	1.26	1.46	3.73	3.93	16.87	13.61	10.76	8.64	40.70	40.27	14.14	11.29
7	KR	11.75	11.53	8.00	8.00	17.33	18.00	14.00	14.04	10.37	10.16	54.85	52.39	15.82	15.15
8	KPR	20.25	18.85	8.00	10.00	32.33	35.33	21.25	21.98	15.99	15.76	56.61	51.43	24.78	23.29
9	TWT	20.93	19.70	10.00	12.00	36.00	32.00	20.20	19.66	13.74	15.92	46.30	65.58	19.26	26.50
10	GYHA	1036.00	1103.45	76.19	180.56	2661.90	2380.95	51.26	38.85	47.60	36.65	86.34	88.97	91.00	71.21

PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation*DA: Days to 50 per cent Anthesis, DS: Days to 50 per cent Silking, PH: Plant height, EH: Ear Placement Height, EL: Ear Length, EG: Ear Girth, KR: Kernel Rows Per Ear, KPR: Kernels Per Row, TWT:100 Grain Weight, GYHA: Total Grain Yield Per Hectare.*
K: Kharif 2023, R: Rabi 2023-2024

Suresh et al. [22], suggesting a significant influence from environmental factors. These findings indicate the presence of non-additive gene actions, which may limit the potential for improvement through selection in these traits.

Genetic advance as a percentage of the mean indicated that these traits are predominantly influenced by additive genetic factors. Utilizing heritability estimates alongside genetic advance enhances the reliability and utility of selection procedures. In the present study, genetic advance was calculated and expressed as a percentage of the mean for all traits (Table 2). High genetic advances were observed for total grain yield (kharif-91, rabi-71.21), followed by ear height (kharif-41.17, rabi-36.08) and number of kernels per row (kharif-24.78, rabi-23.29) in both the seasons. Bharathi et al. [14] reported high genetic advance values for total grain yield and ear height. The high genetic advance values for kernels per row observed in the study align with the findings from Thakur et al. [21] and Wedwessen et al. [23]. Additionally, plant height (20.64) in the kharif season also showed the high genetic advance.

High heritability combined with high genetic advance was observed for traits like ear height and total grain yield in both the kharif and rabi seasons. Additionally, high heritability coupled with high genetic advance was noted for test weight in rabi season only. These findings suggest that these traits are promising targets for improvement through selection, likely driven by additive genetic factors. Kinfe and Tsehaye [24] and Bhiusal et al. [25] reported high genetic advance along with high heritability for grain yield. Similarly, Bekele and Rao [26] documented high genetic advance and higher heritability for 100-seed weight, which aligns with the findings of this study. The results emphasize that, these traits can be enhanced either through selection methods or by progeny selection techniques.

The minimal genetic advance observed for days to 50% anthesis (kharif-9.98, rabi-7.69) and days to 50% silking (kharif-8.31, rabi-6.50) suggests that these traits are primarily governed by non-additive gene action. Ellandula et al. [16] and Gokulakrishnan et al. [20] reported low genetic advance values for days to 50% silking, and Khan et al. [27] for 50% anthesis which were in consistent with the present study. This indicates that these traits are highly influenced by environmental factors, making selection strategies less effective for their improvement.

4. CONCLUSION

The analysis of variance indicated the significant variation among the inbred lines, with phenotypic coefficients of variation (PCV) exceeding genotypic coefficients of variation (GCV) for all traits. The highest PCV and GCV were observed for ear height and total grain yield during both seasons, demonstrating substantial variability among the genotypes. This suggests that direct selection will be effective for improving these traits. High heritability combined with high genetic advance for ear height and total grain yield suggests these traits are governed by additive gene action, making them heritable and fixable, and thus, phenotypic selection for these traits will be beneficial.

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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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