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Assessment of genetic variability, heritability and genetic advance in maize (*Zea mays* L.)

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Abstract

Maize (*Zea mays* L.) is a globally important cereal crop, notable for its adaptability across diverse environments and its role in food, feed, and industrial products. This study investigates the genetic variability, heritability and genetic advance in maize. The crosses were made during *zaid* 2021. Present investigation, conducted on hybrids along with parental lines and check varieties during the *Zaid* season of 2022 at the Agricultural Research farm Pili Kothi, Tilak Dhari Post Graduate College, Jaunpur (U.P.). The mean squares due to treatments were highly significant for all the nineteen characters which showed significant differences, indicating presence of sufficient variability in the materials of F₁s. Phenotypic and genotypic coefficients of variation (PCV and GCV) were higher for traits like seedling fresh weight, seedling dry weight, and grain yield per plant, with values over 20%. High broad-sense heritability estimates were observed for most traits, especially for days to tasseling, plant height, leaf area, and grain yield per plant, while moderate heritability was noted for traits like the number of cobs per plant, cob diameter, and germination percentage. High genetic advance was observed for traits like plant height, leaf area, and seedling weight, with genetic advance percentages exceeding 30% for several traits, indicating potential for genetic improvement. The experiment revealed considerable variation within both parental lines and hybrids, highlighting the potential of hybrid vigor to improve traits such as plant height, leaf area, cob characteristics, and grain yield. This study underscores the complexity of maize breeding and highlights the importance of a comprehensive approach to trait selection and genetic optimization for future breeding programs.

Keywords: Maize (*Zea mays* L.), grain yield, genetic variability, heritability and genetic advance

Introduction

Maize (*Zea mays* L., 2n=20) is one of the most important cereal crops globally, belonging to the tribe Maydeae of the grass family, Poaceae. Originating from Central America, *Zea mays* is the only species within the genus *Zea* with a chromosome number of 2n=20. It shares close genetic relationships with two American Maydeae species *Tripsacum* (gama grass) and *Teosinte* (Euchalaena), the latter being its closest relative. Additionally, it is related to five Asiatic Maydeae species, including *Chinonachne*, *Sclerachne*, *Coix*, *Trilobachene*, and *Polytoca* (Ramadan, *et al.*, 2022) [8]. Maize ranks third in global production, following wheat and rice, owing to its remarkable adaptability across diverse environments. From latitudes 58°N to 40°S, and at elevations ranging from sea level to more than 3000 meters, maize thrives in regions with annual rainfall between 250 to 5000 mm (Wuhaib, *et al.*, 2018) [10]. Its ability to adapt to a wide range of climates, especially in warm temperate and humid subtropical areas, has led to its extensive cultivation worldwide.

Maize is often referred to as the "queen of cereals" due to its high production potential and broad adaptability. In India, it is the fourth most important cereal crop after rice, wheat, and sorghum, with a production of 31.65 million tonnes grown across 9.89 million hectares, yielding an average productivity of 31.99 q/hectare in the 2020-2021 period (Wuhaib, *et al.*, 2018) [10]. Karnataka, a key state in India, leads in maize production, contributing significantly to the country's overall output. Over the years, the area under maize cultivation in India has expanded substantially, with a nearly 16-fold increase in production from 1.73 million tonnes in 1950-51 to 27.8 million tonnes by 2018-2019 (Ramadan, *et al.*, 2022) [8].

Maize's versatility extends beyond food and feed, as every part of the plant—grain, leaves, stalk, tassel, and cob holds economic value. The crop is used in a wide range of food and non-food products, such as starch, oil, protein, alcoholic beverages, sweeteners, and

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pharmaceutical products (El-Moula, *et al.*, 2004) [3]. With applications in over 1000 industrial sectors, maize serves as a vital raw material for producing biodegradable items like packaging, paper, textiles, and cosmetic products. Additionally, it plays a crucial role in animal feed, particularly for poultry and cattle, which accounts for around 63% of maize consumption in India (Aslam *et al.*, 2017) [2].

The global importance of maize is underscored by its cultivation in more than 166 countries, and its role in food security, nutritional enhancement, and income generation for farmers. Maize is particularly well-suited to the Indian agricultural landscape, where it is grown in both traditional maize-growing areas (such as Bihar, Madhya Pradesh, and Uttar Pradesh) and non-traditional regions (including Karnataka and Andhra Pradesh). In recent years, the practice of growing maize during the rabi (winter) season has gained momentum, especially in Bihar, due to its advantages, including lower incidence of pests and diseases and better resource utilization (Aslam *et al.*, 2017) [2].

Maize is a major contributor to global agricultural productivity, with significant implications for both food and industrial sectors. As a crop with diverse uses and a crucial role in global food systems, its continued development through breeding and hybridization is essential (El-Moula, *et al.*, 2004) [3].

Materials and Methods

Experimental Site

The present study was conducted at the Agricultural Research Farm, Pili Kothi, Tilak Dhari Post Graduate College, Jaunpur (U.P.), India, during the Zaid season of 2022. The crosses were made during the Zaid season of 2021, and the evaluation of hybrids, parental lines, and check varieties was carried out in the Zaid season of 2022. Geographically, the experimental site is located at a latitude of 25.720°N and a longitude of 82.700°E, with an altitude of 82 meters above sea level. The area falls within the sub-tropical climatic zone, with sandy loam soil. The region experiences an annual rainfall of approximately 1270 mm, and the climate is semi-arid, characterized by hot summers and cold winters. Presents the detailed weather conditions recorded during the evaluation period of Zaid 2022.

Experimental Materials

Fifteen maize inbred lines were used in the present investigation. These lines were obtained from the Department of Genetics and Plant Breeding, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology (GBPUAT), Pantnagar (Uttarakhand), India.

Experimental Design

A line × tester mating design was used to generate 45 F₁ hybrids by crossing 15 maize inbred lines (females) with three testers (males), namely, Pant 2020 K/1004 (Pragati), Pant 2020 K/1005, and Pant 2020 K/1008. The 45 F₁ hybrids, along with their parental lines and check varieties (Pant 2020 K/1007 and Pant 2020 K/1009 (Surya)), were evaluated in a randomized complete block design (RCBD) with three replications during the Zaid season of 2022. Seeds were sown on 2nd March 2022 in separate plots of 3 meters length, with row spacing of 70 cm and plant-to-plant spacing of 25 cm. All recommended agronomic practices

were followed, and fertilizers were applied at the rate of 120 kg N, 60 kg P, and 60 kg K per hectare.

Statistical analyses

The experimental data collected on all the characters in respect of two experiments of the present study were compiled by taking the mean values over five randomly selected plants in each plot in each replication. It was then subjected to various statistical analyses. The mean data for different traits were subjected for the following statistical analyses such as analysis of variance for Randomized Block Design (Panse and Sukhatme, 1967) [6].

Results and Discussion

Analysis of variance was carried out with respect to nineteen characters to test the significance of differences between various treatments (genotypes) viz., fifteen lines, three testers, forty five F₁s and two checks (Pant 2020k/1007 and Pant 2020 k/1009 (surya)) in Table 1. The mean squares due to treatments were highly significant for all the nineteen characters which showed significant differences, indicating presence of sufficient variability in the materials of F₁s.

Phenotypic and genotypic coefficients of variation (Table 2) (PCV and GCV) were higher for traits like seedling fresh weight, seedling dry weight, and grain yield per plant, with values over 20%. Traits like plant height, leaf area, and cob weight showed moderate variability with PCV and GCV ranging from 10% to 20%. Traits such as germination percentage, days to maturity, and cob diameter exhibited lower variability, with PCV and GCV under 10%. High broad-sense heritability estimates were observed for most traits, especially for days to tasseling, plant height, leaf area, and grain yield per plant, while moderate heritability was noted for traits like the number of cobs per plant, cob diameter, and germination percentage. High genetic advance was observed for traits like plant height, leaf area, and seedling weight, with genetic advance percentages exceeding 30% for several traits, indicating potential for genetic improvement.

The results of the study on various agronomic traits in maize provide valuable insights into the genetic variation and performance of both parental maize varieties and their F₁ crosses (Table 2). The analysis presents a comprehensive view of how different parental lines and their hybrid crosses perform across several traits, including plant height, leaf number, leaf area, maturity, cob characteristics, and seedling performance. These findings are consistent with similar studies by Prakash *et al.* (2019) [7] who observed significant variation in maize traits across different hybrid crosses, and by (Ramadan, *et al.*, 2022) [8], who also reported similar patterns of performance in maize hybrids.

The study on various agronomic traits in maize provides insightful observations regarding the genetic performance of both parental lines and their F₁ hybrids. The results illustrate a significant variation in traits such as plant height, leaf number, leaf area, maturity, cob characteristics, and seedling performance, indicating that there is considerable potential for improvement through hybridization. Similar findings were reported by Prakash *et al.* (2019) [7], who noted substantial genetic variation in key agronomic traits of maize hybrids, underlining the potential for further improvement through hybridization.

Grain yield, a critical trait in maize production, exhibited a similar trend. The F₁ hybrids displayed a range of performances, with some showing yields comparable to or exceeding those of the best-performing parent lines. This demonstrates the potential for improving grain yield through hybridization, with certain hybrids potentially offering better yield efficiency than their parental counterparts. This finding aligns with the work of (Ibrahim, *et al.*, 2021) [5], who showed that hybrid maize can significantly outperform its parental lines in terms of grain yield.

Seedling characteristics, such as seedling length, fresh weight, and dry weight, varied significantly, with some hybrids outperforming their parental lines in terms of vigor. The seed vigor index also showed substantial differences, with some F₁ hybrids demonstrating higher vigor than others. This variability underscores the importance of seedling performance, which influences early plant establishment and can contribute to better growth later in the season. These results are consistent with (Wuhaib, *et al.*, 2018) [10], who reported that hybridization in maize leads to increased seedling vigor, which is crucial for early establishment and growth.

Germination rates were generally high, but again, there were slight differences between the parental lines and the hybrids. The consistency in germination success indicates that both parental lines and F₁ hybrids exhibit good seed viability, which is crucial for ensuring successful crop establishment. This observation aligns with findings by (Wuhaib, *et al.*, 2018) [10], who noted that hybrid maize tends to have high germination rates, contributing to reliable crop establishment and successful growth.

The results from the phenotypic and genotypic coefficients of variation (PCV and GCV) provide a comprehensive insight into the variability of agronomic traits in maize (Table 2). Traits such as seedling fresh weight, seedling dry weight, and grain yield per plant exhibited high variability,

with PCV and GCV values exceeding 20%. This indicates that these traits are highly influenced by genetic factors, making them ideal candidates for selection in breeding programs aimed at improving productivity (Adebayo *et al.*, 2017) [1]. In contrast, traits like plant height, leaf area, and cob weight showed moderate variability with PCV and GCV values between 10% and 20%, suggesting that while genetic factors play a role, environmental influences may also contribute significantly to the expression of these traits (Yahaya, *et al.*, 2028) [11]. Traits such as germination percentage, days to maturity, and cob diameter exhibited low variability, with both PCV and GCV values under 10%, indicating that these traits are relatively stable and less responsive to genetic improvement (Yahaya, *et al.*, 2028) [11].

The high broad-sense heritability observed for most traits, especially for days to tasseling, plant height, leaf area, and grain yield per plant, is promising. High heritability values indicate that these traits are primarily governed by genetic factors, meaning that selection for these traits can be effective in improving maize varieties (Estakhr *et al.*, 2012) [4]. In contrast, moderate heritability estimates for traits such as the number of cobs per plant, cob diameter, and germination percentage suggest that environmental factors also play a considerable role in their expression, making selection for these traits more challenging (Estakhr *et al.*, 2012) [4].

Genetic advance, which is a measure of the potential for genetic improvement through selection, was also high for several traits such as plant height, leaf area, and seedling weight, with genetic advance percentages exceeding 30%. This indicates substantial potential for improving these traits through breeding, especially for traits related to early growth and yield, which are crucial for optimizing maize productivity (Raut, *et al.*, 2017) [9].

Table 1: Analysis of variance for randomized complete block design for 19 characters in maize.

S.N.	Characters	Sources of variation		
		Replications	Treatments	Error
		2	62	124
	d.f.	F _{1s}	F _{1s}	F _{1s}
1	Days to 50 % tasselling	7.000000	68.041475**	1.682796
2	Day to silking	16.925926	73.364226**	1.689367
3	Plant height at 60 DAS	0.253968	1470.563748**	3.721710
4	Number of leaves at 60 DAS	1.333333	2.703533**	1.112903
5	Leaf area at maturity	836.425781	24522.690595**	69.043004
6	Days to maturity	3.873016	29.3222581**	1.523554
7	Number of cob/Plant	0.132275	0.180918**	0.282813
8	Cob length (cm)	2.443228	4.326397**	0.981776
9	Cob diameter (cm)	1.419894	3.868599**	1.053120
10	Cob weight (g)	32.671959	1141.898276**	4.085936
11	Number of grain/cob	145.798935	9689.926950**	95.229049
12	100 kernel weight (g)	3.561481	11.224712**	1.189600
13	Grain yield/Plant (g)	5.714859	2459.907905**	1.381069
14	Shelling Percent	0.506956	90.660316**	1.167700
15	Seedling length (cm)	4.251640	16.477651**	1.012554
16	Seedling fresh weight(g)	0.014248	0.448318**	0.003424
17	Seedling dry weight (g)	0.000178	0.004913**	0.000415
18	Seed vigor index	37909.484375	15704	9490.804727
19	Germination percentage	0.362063	4.350845**	1.331096

*,** Significant at 5% and 1% probability levels, respectively.

Table 2: Estimates of general mean, phenotypic (PCV) and genotypic (GCV) coefficient of variation, heritability in broad sense (h^2_{bs}) and genetic advance in percent of mean for 19 characters in maize

S. N.	Characters	General mean $\pm$ SE	Coefficient of variation (%)		Heritability in broad sense (%)	Genetic advance in percent of mean
			PCV	GCV		
		F _{1s}	F _{1s}	F _{1s}	F _{1s}	F _{1s}
1	Day to 50 % tasselling	58.06 $\pm$ SE0.74	8.2021	8.100	97.53	16.4784
2	Days to silking	65.83 $\pm$ SE0.75	7.51145	7.4244	97.70	15.1171
3	Plant height at 60 DAS(cm)	138.12 $\pm$ SE1.11	16.0289	16.008	99.75	32.9359
4	Number of leaves at 60 DAS	13.57 $\pm$ SE0.60	6.9949	5.3654	58.84	8.4778
5	Leaf area at maturity	583.26 $\pm$ SE4.79	15.5010	15.4792	99.72	31.8422
6	Days to maturity	113.55 $\pm$ SE0.71	2.7532	2.6807	94.80	5.3768
7	Number of cob/plant	2.4392 $\pm$ SE0.30	10.0680	7.5557	-56.32	-11.6809
8	Cob length(cm)	16.26 $\pm$ SE0.57	7.3844	6.4927	77.31	11.7599
9	Cob diameter(cm)	15.80 $\pm$ SE0.59	7.1867	6.1310	72.78	10.7745
10	Cob weight(g)	157.72 $\pm$ SE1.16	12.3695	12.3474	99.64	25.3900
11	Number of grains/cob	463.05 $\pm$ SE5.63	12.2735	12.2131	99.02	25.0350
12	100 kernel weight (g)	17.24 $\pm$ SE0.62	11.2174	10.6063	89.40	20.6588
13	Grain yield/plant(g)	141.05 $\pm$ SE0.67	20.3013	20.2956	99.94	41.7972
14	Shelling Percent	53.61 $\pm$ SE0.62	10.2531	10.1869	98.71	20.8494
15	Seedling length(cm)	18.61 $\pm$ SE0.58	12.5922	12.1992	93.85	24.3460
16	Seedling fresh weight (g)	1.4920 $\pm$ SE0.03	25.9096	25.8104	99.24	52.9660
17	Seedling dry weight (g)	0.19 $\pm$ SE0.01	20.8402	19.9409	91.56	39.3056
18	Seed vigor index	1751.11 $\pm$ SE56.24	13.0656	12.6647	93.96	25.2886
19	Germination percentage	94.082 $\pm$ SE0.66	1.2800	1.0664	69.41	1.8301

Conclusion

The present study demonstrates significant genetic variability among the evaluated maize genotypes, including parental lines, F₁ hybrids, and checks, for a wide range of agronomic traits. High phenotypic and genotypic coefficients of variation (PCV and GCV) observed for traits such as seedling fresh weight, seedling dry weight, and grain yield per plant suggest these traits are strongly influenced by genetic factors, making them suitable targets for selection and improvement. The high broad-sense heritability and genetic advance associated with traits like plant height, leaf area, and seedling weight further highlight their potential for enhancement through breeding. Furthermore, the superior performance of certain F₁ hybrids in terms of grain yield and seedling vigor indicates the effectiveness of hybridization in enhancing productivity. The findings align well with previous studies, supporting the viability of selecting high-performing hybrids for further breeding efforts aimed at improving maize yield.

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