Analyzing the variability in Maize (*Zea mays* L.) genotypes using principal component analysis under varied ecosystems

Abstract

Maize is a cereal cross-pollinated crop which belongs to the family poaceae. It is grown over a wider range of environment than any other cereal crop. The present study was conducted to study genetic variability using principal component analysis. Twenty maize genotypes were used in the study. Ten characters *viz*., plant height, ear height, days to 50 % tasselling, days to 50 % silking, ASI, cob length, number of rows per cob, hundred seed weight, shelling percentage and yield were recorded for the study. In the PCA, four principal components exhibited eigen value more than 1.0 exhibiting 84.54 percent of the variability for the characters under irrigated conditions. The PC1 negative loadings for the flowering traits, *viz*., days to 50 % silking (-0.3886), ASI (-0.3233) and days to 50 % tasselling (-0.2972) and positive loadings with higher contribution from cob length (0.4033), no of rows per cob (0.3480) followed by shelling percentage were observed. Positive loadings were exhibited by days to tasselling (0.4780), plant height (0.4670) and hundred seed weight (0.4518) in PC2. In PC3 positive loadings for the characters *viz*., number of rows per cob (0.5338), ASI (0.5226) and cob length (0.3299) and negative loadings for the traits grain yield (-0.3815), ear height (-0.2658) and plant height (-0.2437) and in PC4 positive loadings for plant height (0.4953), ear height (0.2546) and negative loadings were shown by days to grain yield (-0.6632), shelling percentage (-0.3751), ASI (-0.2369) and 50 % silking (-0.0648) were observed. In rainfed conditions, the two principal components had eigen value of more than 1. Under normal irrigated condition, PC1 and PC2 had eigen value of 5.689 and 1.6439. Plant height (0.3866), cob length (0.3726), number of rows per cob (0.3551), shelling % (0.3196), grain yield (0.2941), and hundred seed weight (0.2847) contributed positively to PC1. PC 2 had highest positive contributions from days to 50 % tasselling (0.5676), days to 50 % silking (0.5249), shelling % (0.3885), hundred seed weight (0.3763) and grain yield (0.2007). Negative loadings were shown by ear height (-0.1356) and plant height (-0.0093). Positive loadings were contributed by days to 50 % tasselling (0.5676), Days to 50 % silking, shelling percentage (0.3885) and hundred grain weight (0.3763).

Key words: PCA, anthesis silking interval, cob length, number of rows per cob and grain yield

Introduction

Maize, a cereal crop is the third important food crop in the world having highest yield potential. The crop requires 500 mm of rainfall for a season. However, in rainfed farming systems, where precipitation is uncertain, the crop has chance of exposing to climate variability and stress. Over the last two decades, drought caused a direct loss of USD 29 billion in developing countries (FAO 2021). Among the maize growing countries in the world, India rank 4th in area and 7th in production, representing around 4% of the world maize area and 2% of total production. It has diversified uses as human food, animal feed and as a source for large number of industrial products. Maize has 60-70% of carbohydrates, 9-11.5% of crude protein, 2-3.5% crude fibre and 3-5% of lipids. This crop is used to a higher level of industrial utilization than any other cereal grain because of its very high production potential, wider adaptability industrial value. (Kannaiyan *et al.* 2000 and Bharathi *et al* 2021). Maize starch is used for the production of glucose, dextrose ethyl alcohol, acetone and lactic acid. It is also used in making adhesive, preservatives, and antiseptic agents. By products obtained in the manufacturing of maize starch is used as cattle feed. The corn oil finds many uses in the industry. Maize is the prime driver of world agricultural economy due to its multiple uses. There is an urgent need to increase the production and productivity of maize crop to meet the demand of the ever-growing population (Fang and Xiong 2015). This role requires an increase in crop yields either by reducing the gap between potential and actual yields (Premalatha and Kalamani, 2010). Plants exhibit multiple plant metabolic pathways prevented plants from senescing under water limited conditions (Zhang *et al.*, 2018). Hence, there is a need to understand the factors that can contribute to improvements in maize productivity, reduce the yield gap and enhance food security. Principal Component Analysis (PCA) can be used to find out the relative contribution of the traits towards the total variability (Zaman and Alam, 2013 & Gupta and Khandelwal 2022). Genotypes with narrow genetic base are vulnerable to biotic and abiotic stress and genetically diverse genotypes is highly essential for any crop improvement programme (Yadav *et al* 2011). The main aim is to extract the total variation of characters into a limited number of factors (Kanganathakur and Sarma 2023). The present investigation is done to dissect out the traits contributing the grain yield by Principal Component Analysis.

Materials and methods

The experiment was conducted in Maize Research Station, Tamil Nadu Agricultural University during Rabi 2021 - 22. The study was conducted with twenty-two hybrids raised in Randomized block design in two replications. The genotypes were raised in irrigated and rainfed conditions simultaneously. The genotypes were raised in two rows of 4 m length and spacing of 60 cm x 25 cm. All the recommended management practices were adopted for the crop. The biometrical traits *viz*., plant height, ear height, days to 50 % tasselling, days to 50 % silking, ASI, cob length, number of rows per cob, hundred seed weight, shelling percentage and yield were recorded in the twenty-two genotypes used for the study. The plant traits that contributed to the maximum variation among the maize genotypes were identified by PCA method using STAR software.

Results and Discussion

The results on the study of principal component analysis for grain yield and the yield associated traits under irrigated condition and rainfed condition is presented in the table 1. Out of 10 components, only four principal components exhibited eigen value more than 1.0 and showed 84.54 percent of the variability for the characters. The PC1, PC2, PC3 and PC4 exhibited 39.79, 20.67, 12.73 and 11.35 percent of variability respectively. Mehrnaz *et al.,* (2014), Muhammad *et al.,* (2015) and Hughes *et al.*, (2015) had studied the genetic divergence studies in maize using principal component analysis. The PC1 with eigen value of 3.97 had negative loadings for the flowering traits, *viz*., days to 50 % silking (-0.3886), ASI (-0.3233) and days to 50 % tasselling (-0.2972). The remaining traits showed positive loadings with higher contribution from cob length (0.4033), no of rows per cob (0.3480) followed by shelling percentage. In PC2 all the traits showed positive loadings except number of rows per cob. Days to tasselling (0.4780), plant height (0.4670) and hundred seed weight (0.4518) had the highest positive loadings. The PC3 with eigen value of 1.272 exhibited 12.73 % variability with positive loadings for the characters *viz*., number of rows per cob (0.5338), ASI (0.5226) and cob length (0.3299) and negative loadings for the traits grain yield (-0.3815), ear height (-0.2658) and plant height (-0.2437). PC4 had eigen value of 1.135 and variability of 11.35 %. Negative loadings were shown by days to grain yield (-0.6632), shelling percentage (-0.3751), ASI (-0.2369) and 50 % silking (-0.0648). In rainfed conditions, the two principal components had eigen value of more than 1. PC1 had eigen value of 5.689. Positive loadings were contributed by the plant height (0.3866), cob length (0.3726), number of rows per cob (0.3551), shelling percentage (0.3196), grain yield (0.2941) and hundred seed weight (0.2847). Similar PCA study was reported by Ali *et al* 1999. PC 2 had eigen value of 1.6439 with highest positive contributions from days to 50 % tasselling (0.5676), days to 50 % silking (0.5249), shelling % (0.3885), hundred seed weight (0.3763) and grain yield (0.2007). Negative loadings were shown by ear height (-0.1356) and plant height (-0.0093). Principal component analysis, resulted in more divergent assessment under normal irrigated conditions with four numbers of principal components with eigenvalue ≥ 1 and cumulative variability of 84.54 percent. Under water limited rainfed conditions, two number of principal components with eigenvalue ≥ 1 were observed with cumulative variability of 73.34. The trend of the scree plot (Fig.1.) and the biplot of the principal components under normal irrigated and rainfed conditions are represented in the Fig. 2&3 respectively. The different principal components with important characters coming together and contributing towards variability have the tendency to remain interrelated (Sinha and Mishra 2013).

Conclusion

Thus, for a trait-based selection, elucidation of the relative merits of component traits will be the basis for planning maize improvement programme. Cob length, days to 50 % silking, no of kernel rows per cob is found to contribute maximum genetic variability in maize. Therefore, using the above results, selection of genetically diverse genotypes will help in evolving new highly heterotic adaptive hybrids in crop breeding programmes under varying ecological and stress conditions.

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Table 1. Eigen Values, Proportion of Variance and Cumulative Proportion of maize genotypes under irrigated and rainfed conditions

PC	**Normal irrigated conditions**			**Rainfed conditions**		
Principal Components	**Eigen Values**	**Proportion of Variance**	**Cumulative Proportion**	**EigenValues**	**Proportion of Variance**	**Cumulative Proportion**
PC1	3.9789	0.3979	0.3979	5.6895	0.5689	0.5689
PC2	2.0671	0.2067	0.6046	1.6439	0.1644	0.7333
PC3	1.2727	0.1273	0.7319	0.8336	0.0834	0.8167
PC4	1.1354	0.1135	0.8454	0.7640	0.0764	0.8931
PC5	0.6161	0.0616	0.9070	0.4858	0.0486	0.9417
PC6	0.4143	0.0414	0.9485	0.2345	0.0234	0.9651
PC7	0.2621	0.0262	0.9747	0.1810	0.0181	0.9832
PC8	0.1551	0.0155	0.9902	0.1178	0.0188	0.9950
PC9	0.0983	0.0098	1.0000	0.0499	0.0050	1.0000

Table 2. Contribution of first four principal components to variation of maize genotypes under irrigated and rainfed conditions

Parameters	**Normal irrigated conditions**				**Rainfed conditions**	
	PC1	**PC2**	**PC3**	**PC4**	**PC1**	**PC2**
Plant height	0.0245	0.4670	-0.2437	0.4963	0.3866	-0.0093
Ear height	0.3102	0.2123	-0.2658	0.2546	-0.3378	-0.1356
Days to 50 % tasselling	-0.2972	0.4780	-0.1204	0.0683	-0.2242	0.5676
Days to 50 % silking	-0.3886	0.3804	0.1662	-0.0648	-0.2987	0.5249
ASI	-0.3233	0.0260	0.5226	-0.2369	0.2498	0.1573
Cob length	0.4033	0.1434	0.3299	0.0015	0.3726	0.1327
No of kernel rows per cob	0.3480	-0.0142	0.5388	0.1759	0.3551	0.0929
HSW	0.3334	0.4518	0.0742	0.1118	0.2847	0.3763
Shelling %	0.3433	0.3394	0.0672	-0.3751	0.3196	0.3885
Grain yield	0.2155	0.1516	-0.3815	-0.6632	0.2941	0.2007

Fig. 1. Scree plot under irrigated and rainfed conditions

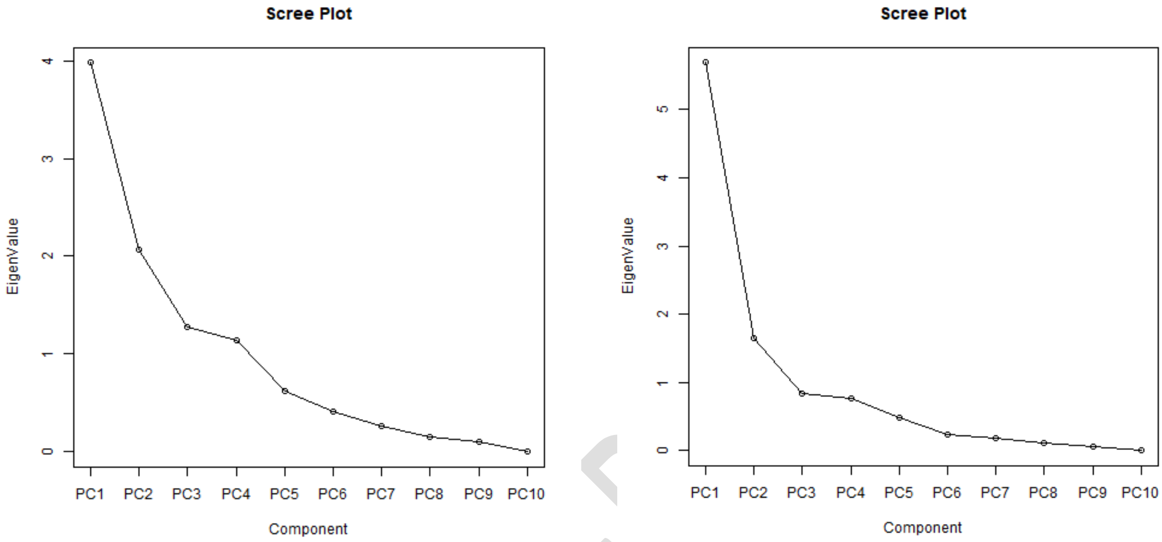

Fig. 2. Principal Component Analysis – Biplot (irrigated condition)

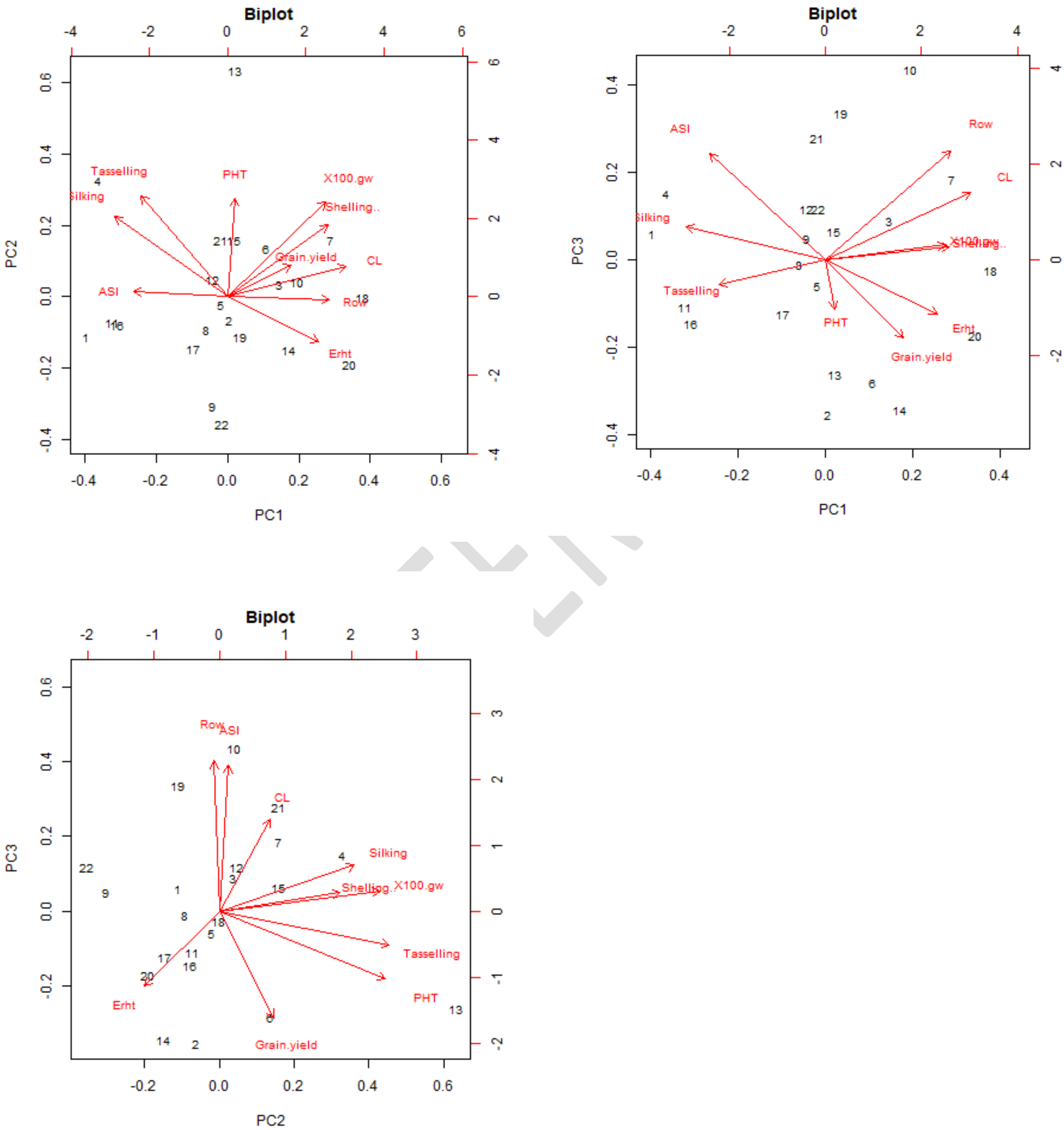

Fig. 3. Principal Component Analysis – Biplot (rainfed condition)