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Principal component analysis in maize land races (*Zea mays* L.) under irrigated and moisture stress conditions

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ABSTRACT

In the present study, 18 genotypes of maize were evaluated under irrigated and moisture stress conditions in RBD during the post rainy season 2021-22 at ARS, Karimnagar to estimate the contribution of fourteen quantitative traits to the total variability through Principal component analysis. Out of fourteen , five principal components (PCs) exhibited greater than 1.00 Eigen value under irrigated and moisture stress conditions, and explained 87.05% and 91.44% cumulative variability under irrigated and stress conditions, respectively. The PC1 displayed 31.20% and 51.72% up to PC2 and PC3 51.33% , 65.71 and 68.21%, 77.49% cumulative variability was observed among the landraces under irrigated and stress conditions, respectively. The first principal component PC1 was positively contributed mainly by two characters viz., Shelling % and SPAD Chlorophyll content under both conditions. The second principal component PC2 was contributed mostly by grain yield plant-1 and yield attributing traits i.e.ear length, ear diameter , number of kernel rows ear-1, number of kernels row-1 and thousand kernel weight. Based on principal component analysis the landraces IC 611609 and IC 627707 had maximum contribution for yield attributing traits. This study will identify variability contributing parameters and selection of suitable genotypes for breeding and utilization in maize improvement for yield attributing traits.

Keywords: *Component, analysis, maize, Zea mays*

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INTRODUCTION

Maize is an important cereal crop for billions of people as food, feed, and industrial raw material. Currently, nearly 1147.7 million MT of maize is being produced together by over 170 countries from an area of 193.7 MHa with an average productivity of 5.75 t/ha (FAOSTAT, 2020). Maize production in India has increased more than 16 times from a mere 2 million tons in 1949-50 to 31.65 million tons and presently it occupies 9.89 MHa area with a mean yield of 3.19 t ha^{-1} (IndiaAgriStat.com, 2020-21) contributing to 9% of the Indian food basket. It is being estimated that the demand for maize will continue to increase given increasing demand in poultry and livestock sectors in the country and growing non-vegetarian population and changing food habits (India-Maize-Summit, Agri Vision, 2022). To meet the growing demand, enhancement of maize yield in coming years across all the growing locations in India is a big challenge in the era of climate change.

Crop improvement is a continuous process and the major objective of the maize breeding programmes is to develop high yielding and adapted hybrids to the present climate change scenario. Identification of diverse parents with broad genetic bases is of utmost importance to combine desirable traits into a genotype. Hence, sound knowledge of genetic diversity and variability is crucial to undertake any recombination breeding program. Multivariate statistical techniques are used to analyze multiple measurements of each individual in genetic diversity. Among the various multivariate techniques, principal component analysis (PCA) is powerful in selecting genotypes to meet the objectives of a plant breeder [5]. PCA may be used to reveal patterns and eliminate redundancy in the data as morphological and physiological variations routinely occur in crop species.

MATERIALS AND METHODS

Experimental material

The present study was undertaken during the post-rainy season, 2021-22 at the Agricultural research station, Karimnagar using 18 maize germplasm lines obtained NBPGR, Hyderabad. Each entry was sown in two rows of 3m length with a spacing of 60cmx20cmin RBD replicated thrice. Recommended package of practices were followed to raise a good crop. The data were recorded on five randomly chosen plants for quantitative characters *viz.,* plant height, ear height, cob length, cob girth, number of kernel rows ear^{-1}, number of kernels row^{-1}, shelling percent, testweight and SPAD values while the remaining traits *i.e.,* days to 50% tasseling, days to 50% silking and days to maturity were recorded on plot basis. The mean values were subjected to the Principal Component Analysis (R studio team, 2022).

RESULTS AND DISCUSSION

The results of the Principle Component Analysis revealed the existence of genetic variability among the genotypes for yield and yield contributing traits. Principal components having eigen values and variation of more than 1 and 4%, respectively were defined as the main PC [1]. Final output of PCA explained the genetic diversity that existed in maize genotypes for the studied traits. Eigen values' explain the importance and contribution of each component to total variance, whereas degree of contribution of each trait with each principal component was indicated by the coefficient of Eigen vectors. No standard tests are available to test the significance of Eigen values and the coefficients [4] (Table 1 and Figure 1). The traits that explain the major variability in different principal components must be given due consideration in breeding [2].

In Principle Component Analysis, among the fourteen traits only five principal components (PCs) had shown more than 1.00 eigen value with 87.05 and 91.44 % cumulative variability under irrigated and stress conditions, respectively. The remaining principal components were rejected as eigen values were less than one. Hence, these five PCs were the main principal components and of these, PC1 had the highest variability (31.20%) followed by PC2 (20.13%) under irrigated conditions and stress conditions PC1 had the highest variability (28.93%) followed by PC2 (22.79 %).

Two traits *viz.,* shelling % (0.206 & 0.248, respectively)and SPAD Chlorophyll content (0.162 & 0.163, respectively) contributed majorly to the first principal component PC1 under irrigated and stress conditions, respectively. The second principal component PC2 under irrigated conditions was contributed mainly by grain yield plant^{-1} (0.341) followed by SPAD Chlorophyll content (0.241), ear length (0.213), ear diameter (0.193),number of kernel rows ear^{-1} (0.160), number of kernels row^{-1} (0.152) and thousand kernel weight (0.149). On the contrary, flowering and maturity traits, plant height, ear height and shelling % were negatively correlated with PC2 suggesting these traits will enhance the yield and yield contributing traits. Aiming improvement of a yield trait will direct the improvement of other yieldrelated traits in the same PC as long as they have the same positive effect. Similar findings were obtained under stress conditions also.

The third principal component PC3 was dominated by plant height (0.601), ear height (0.566),shelling % (0.327), number of kernels row^{-1} (0.168) and thousand kernel weight (0.094) under irrigated conditions. The same PC under stress conditions consists of days to 50% pollen shed (0.119), days to 50% silk emergence(0.196), anthesis-silking Interval (0.569) and days to 75% maturity (0.209) . The fourth principal component PC 4 was positively associated with grain yield plant^{-1} (0.033 & 0.015, respectively),days to 50% pollen shed (0.248 and 0.334, respectively), days to 50% silk emergence(0.146 & 0.236, respectively), days to 75% maturity (0.118& 0.250, respectively),

Table 1: Eigen values, % variance and cumulative Eigen values of germplasm under irrigated and stress conditions

Traits	PC	Eigen value		Percentage of variation		Cumulative %	
		Irrigated	Stress	Irrigated	Stress	Irrigated	Stress
Grain yield (kg ha^{-1})	PC1	4.37	4.05	31.20	28.93	31.20	51.72
Days to 50% pollenshed	PC2	2.82	3.19	20.13	22.79	51.33	65.71
Days to 50% silk emergence	PC3	2.36	1.96	16.88	13.99	68.21	77.49
Anthesis Silking Interval	PC4	1.50	1.65	10.72	11.78	78.93	85.48
Days to 75% maturity	PC5	1.14	1.12	8.12	7.99	87.05	91.44
Plant height (cm)	PC6	0.66	0.83	4.71	5.96	91.76	95.53
Ear height (cm)	PC7	0.50	0.57	3.59	4.09	95.35	97.38
Ear length (cm)	PC8	0.28	0.26	1.99	1.85	97.34	98.59
Ear diameter (cm)	PC9	0.17	0.17	1.19	1.21	98.53	99.48
Number of kernel rows ear^{-1}	PC10	0.09	0.12	0.67	0.89	99.20	99.89
Number of kernels row^{-1}	PC11	0.06	0.06	0.42	0.41	99.62	99.96
Thousand kernel weight (g)	PC12	0.04	0.01	0.26	0.07	99.88	100.00
Shelling (%)	PC13	0.02	0.00	0.11	0.04	99.99	100.00
SPAD chlorophyll	PC14	0.00	0.00	0.01	0.00	100.00	51.72

Table 2: Principle components for yield and yield attributing traits in maize genotypes under irrigated and stress conditions

Traits	PC1		PC2		PC3		PC4		PC5		PC6	
	I	S	I	S	I	S	I	S	I	S	I	S
Grain yield (kg ha^{-1})	-0.348	-0.357	0.341	0.233	-0.114	-0.217	0.033	0.015	-0.140	-0.235	0.016	0.180
Days to 50% pollenshed	-0.267	-0.338	-0.452	-0.313	-0.004	0.119	0.248	0.334	-0.011	0.032	0.012	-0.031
Days to 50% silk emergence	-0.266	-0.364	-0.469	-0.299	-0.078	0.196	0.146	0.236	-0.053	0.007	-0.035	-0.038
Anthesis Silking Interval	-0.050	0.105	-0.106	0.092	-0.368	0.569	-0.557	-0.198	-0.181	-0.202	-0.279	-0.322
Days to 75% maturity	-0.253	-0.353	-0.477	-0.307	0.011	0.209	0.118	0.250	-0.039	-0.015	-0.061	-0.035
Plant height (cm)	-0.021	0.111	-0.068	-0.408	0.601	-0.284	-0.205	-0.273	0.023	0.034	-0.153	-0.265
Ear height (cm)	-0.080	0.002	-0.068	-0.426	0.566	-0.406	-0.162	-0.152	0.178	0.135	-0.369	0.015
Ear length (cm)	-0.374	-0.351	0.213	0.142	-0.103	0.001	-0.144	-0.392	-0.134	0.023	-0.415	0.104
Ear diameter (cm)	-0.406	-0.295	0.193	0.202	0.062	-0.414	0.104	0.113	0.181	0.159	0.309	-0.123
Number of kernel rows ear^{-1}	-0.227	-0.225	0.160	0.241	0.071	-0.162	0.389	0.131	-0.520	-0.514	-0.149	-0.437
Number of kernels row^{-1}	-0.317	-0.273	0.152	-0.096	0.168	-0.029	-0.203	-0.483	-0.235	-0.403	0.017	0.256
Thousand kernel weight (g)	-0.370	-0.236	0.149	0.161	0.094	0.009	-0.068	-0.245	0.398	0.448	0.342	-0.627
Shelling (%)	0.206	0.248	-0.006	-0.288	0.327	-0.180	0.001	0.064	-0.587	-0.478	0.382	-0.337
SPAD chlorophyll content	0.162	0.163	0.241	0.266	0.029	-0.239	0.543	0.389	0.100	-0.029	-0.451	-0.011

Table 2: Principle components for yield and yield attributing traits in maize genotypes under irrigated and stress conditions

Traits	PC1		PC2		PC3		PC4		PC5		PC6	
	I	S	I	S	I	S	I	S	I	S	I	S
Grain yield (kg ha^{-1})	-0.348	-0.357	0.341	0.233	-0.114	-0.217	0.033	0.015	-0.140	-0.235	0.016	0.180
Days to 50% pollenshed	-0.267	-0.338	-0.452	-0.313	-0.004	0.119	0.248	0.334	-0.011	0.032	0.012	-0.031
Days to 50% silk emergence	-0.266	-0.364	-0.469	-0.299	-0.078	0.196	0.146	0.236	-0.053	0.007	-0.035	-0.038
Anthesis Silking Interval	-0.050	0.105	-0.106	0.092	-0.368	0.569	-0.557	-0.198	-0.181	-0.202	-0.279	-0.322
Days to 75% maturity	-0.253	-0.353	-0.477	-0.307	0.011	0.209	0.118	0.250	-0.039	-0.015	-0.061	-0.035
Plant height (cm)	-0.021	0.111	-0.068	-0.408	0.601	-0.284	-0.205	-0.273	0.023	0.034	-0.153	-0.265
Ear height (cm)	-0.080	0.002	-0.068	-0.426	0.566	-0.406	-0.162	-0.152	0.178	0.135	-0.369	0.015

continued..

Ear length (cm)	-0.374	-0.351	0.213	0.142	-0.103	0.001	-0.144	-0.392	-0.134	0.023	-0.415	0.104
Ear diameter (cm)	-0.406	-0.295	0.193	0.202	0.062	-0.414	0.104	0.113	0.181	0.159	0.309	-0.123
Number of kernel rows ear^{-1}	-0.227	-0.225	0.160	0.241	0.071	-0.162	0.389	0.131	-0.520	-0.514	-0.149	-0.437
Number of kernels row^{-1}	-0.317	-0.273	0.152	-0.096	0.168	-0.029	-0.203	-0.483	-0.235	-0.403	0.017	0.256
Thousand kernel weight (g)	-0.370	-0.236	0.149	0.161	0.094	0.009	-0.068	-0.245	0.398	0.448	0.342	-0.627
Shelling (%)	0.206	0.248	-0.006	-0.288	0.327	-0.180	0.001	0.064	-0.587	-0.478	0.382	-0.337
SPAD chlorophyll content	0.162	0.163	0.241	0.266	0.029	-0.239	0.543	0.389	0.100	-0.029	-0.451	-0.011

Table 3: Rotated matrix results of yield and its related traits of maize under irrigated and stress conditions

PC1		PC2		PC3		PC4		PC5		PC6	
I	S	I	S	I	S	I	S	I	S	I	S
ASI	PLHT	GY	GY	PLHT	ASI	DT	DT	TW	EHT	ED	KPR
	Sh (%)	EL	EL	EHT		DS	DS		TW	Sh (%)	
			ED	KPR		DM	DM				
			NKRE			NKRE	SPAD				
						SPAD					

Table 5: Genotypes selected on the basis of PC score in each component with highest positive values under irrigated and stress conditions

S.No.	PC1		PC2		PC3		PC4		PC5		PC6	
	I	S	I	S	I	S	I	S	I	S	I	S
1	IC 611611	IC 611611	IC 611609	IC 623877	IC 611611	IC 611611	IC 611609	IC 623880	IC 627707	IC 623878	IC 623877	IC 611611
2	IC 623875	IC 623875	IC 623880	IC 623880	IC 636965	IC 623873	IC 623878	IC 627708	IC 636965	IC 627704	IC 623878	IC 636965
3	IC 623878	IC 623878	BML-6	IC 636965	IC 636977	IC 623875	IC 623879	KML-109		IC 627707	IC 627708	KML-109
4	IC 627704	IC 627704	BML-7	IC 636977		IC 636977				IC 636965		
5	BML-6	BML-6		BML-6								
6	BML-7	BML-7		BML-7								
7	KML-109	KML-109										

Table: PCA scores of maize genotypes under irrigated and stress conditions

Genotypes	PC1		PC2		PC3		PC4		PC5		PC6	
	I	S	I	S	I	S	I	S	I	S	I	S
IC 611609	-4.679	-3.322	1.963	0.469	-0.351	0.373	1.8	-2.829	-1.379	-1.499	-0.895	0.957
IC 611611	2.708	1.522	-0.285	0.373	1.023	1.561	0.714	-0.595	-0.74	-0.286	-0.587	1.918
IC 611615	-1.617	-1.635	-1.139	-0.838	-0.181	-0.605	0.636	0.238	0.627	0.926	-0.02	-1.123
IC 623873	-1.339	-0.971	0.393	0.528	-0.063	1.497	0.513	-0.556	-0.991	-0.658	0.342	-0.339
IC 623875	2.689	1.374	-2.332	-0.169	0.886	3.039	0.611	-0.894	-1.011	-0.077	-0.421	-1.636
IC 623877	-0.139	-0.36	0.862	1.173	-0.217	-0.485	-0.995	0.476	0.388	-0.757	1.02	-1.307
IC 623878	1.433	1.525	-0.892	-3.049	0.192	0.196	3.03	-0.984	0.471	1.022	2.045	0.877
IC 623879	-1.05	-0.217	0.651	0.528	0.206	-1.804	1.181	-1.497	0.218	0.276	-0.289	-0.584
IC 623880	0.928	0.308	2.478	1.139	-0.508	-1.535	-1.233	1.723	-0.785	-1.013	0.79	-0.266
IC 627704	2.082	2.341	-1.958	-3.463	-3.499	0.329	0.016	-0.118	0.385	1.341	-0.777	-0.755
IC 627705	-1.583	-1.55	-0.407	-2.395	-1.804	-1.195	-1.377	0.407	-1.286	-1.018	-0.144	-0.158
IC 627707	-2.301	-2.798	-0.619	0.454	-0.692	-0.929	-0.783	-0.767	2.264	1.061	-0.416	-0.136
IC 627708	-1.851	-2.705	-3.223	-1.265	-0.016	0.376	-1.915	2.849	-0.111	-0.215	1.15	0.459
IC 636965	-0.61	-0.66	0.291	2.575	2.211	-0.304	0.27	0.752	2.451	2.737	-0.804	1.185
IC 636977	-0.781	-1.178	-0.177	2.095	4.009	2.109	-1.344	0.879	-0.851	0.353	0.109	-0.187
BML-6	1.025	3.242	3.177	1.726	-1.673	-2.693	-0.174	-1.166	0.595	-0.177	0.492	-0.082
BML-7	3.808	3.801	2.354	2.326	0.633	0.588	-1.022	0.995	0.394	-0.783	-0.467	0.077
KML-109	1.276	1.283	-1.136	-2.208	-0.155	-0.518	0.070	1.088	-0.638	-1.234	-1.127	1.100

ear diameter (0.104 & 0.113, respectively), the number of kernel rows ear-1 (0.389 & 0.131, respectively) and SPAD Chlorophyll content(0.543 & 0.389, respectively) under irrigated and stress conditions, respectively. The fifth principal component PC5 was related to plant height (0.023 & 0.034, respectively), ear height (0.178 & 0.135, respectively),ear diameter (0.181 & 0.159 respectively) and thousand kernel weight (0.398 & 0.448, respectively) under irrigated and stress conditions, respectively(Table 2, 3 and Figure 2).Similarly, [6] reported that five principal components with eigen value greater than >1 explained 81.62 % of the cumulative variation and [3] mentioned four principal components with eigen value >1 contributed to 72.48% of total variation.

Based on principal component analysis as depicted in Figure 2, the landraces IC 611609 and IC 627707 had shown maximum contribution for yield attributing traits

PC scores of genotypes

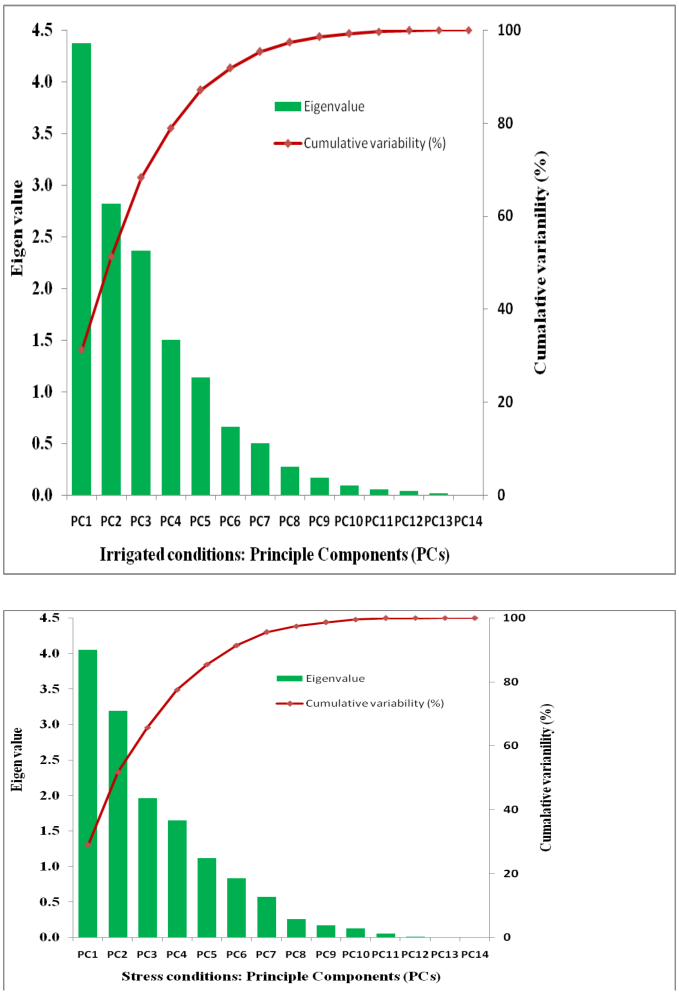

Fig 1: Scree plot under irrigated (1 a) and stress (1 b) conditions

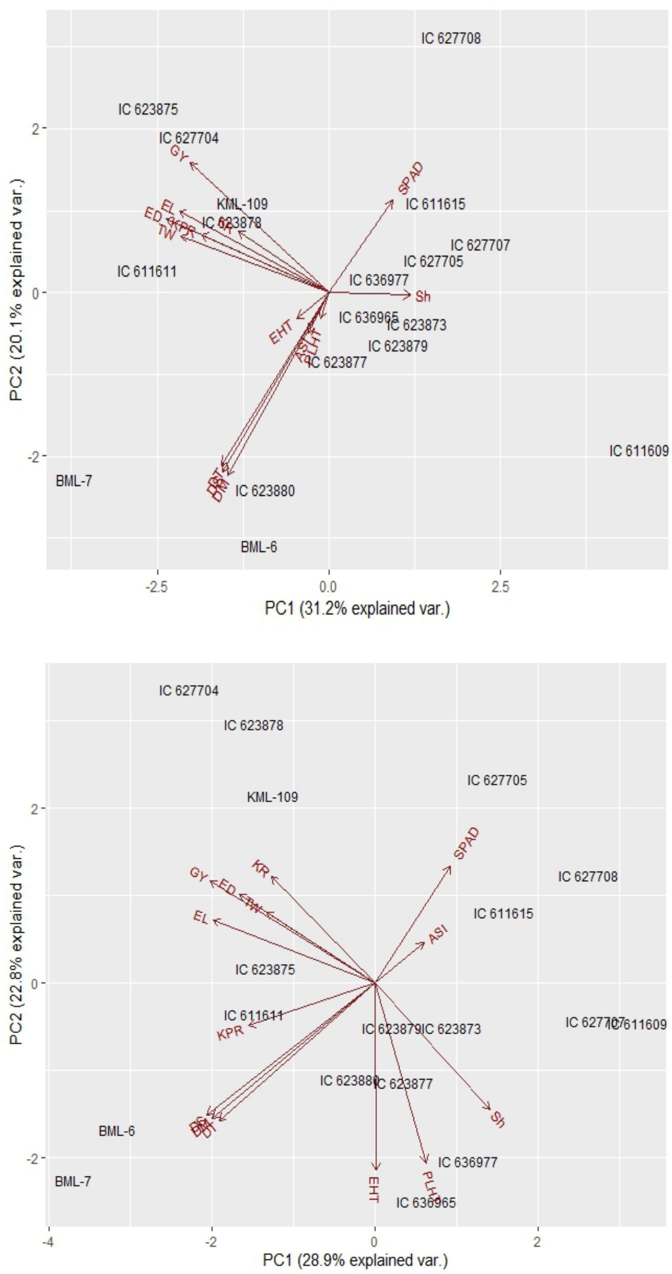

Fig 2: Biplot of Principle components under irrigatedand stress conditions

In the Table 4, principal components (PC1, PC2, PC3 and PC4) had positive and negative values. Principal component scores explain the variability of each component and a high PC score for a particular genotype in a particular principal component indicate high values for the variables in that genotype.

Promising genotypes with the highest PC scores were mentioned in Table 5. BML-7 had the highest PC1 score followed by IC 611611 and IC 623875 under irrigated conditions and BML-7 followed by BML-6 and IC 627704 possessed high scores under stress conditions revealing genotypes mentioned in particular conditions had high values for anthesis- silking Interval under irrigated and for plant height and shelling % under stress conditions. For PC2, genotype BML-6 followed by IC 623880 and BML-7 had high scores under irrigated conditions while, IC 636965 followed by BML-7 and IC 636977 obtained high scores under stress conditions. It indicated that these genotypes possessed high values for ear diameter and the number of kernel rows ear^{-1} under stress conditions and for grain yield and ear length under both conditions. Genotype IC 636977 followed by IC 636965 and IC 623875 followed by IC 636977 had high PC3 values under irrigated and stress conditions, respectively and the genotypes mentioned under particular environment related to plant height, ear height and the number of kernels row^{-1} in irrigated conditions and anthesis-silking interval in stress conditions. IC 623878 followed by IC 611609 and IC 627708 followed by IC 623880 had high PC4. The highest PC score was obtained by IC 623878 followed by IC 611609 in PC4 for flowering and maturity traits, SPAD and number of kernel rows ear^{-1} under irrigated conditions and genotype IC 627708 followed by IC 623880 for all these mentioned traits except number of kernel rows ear^{-1}under stress conditions.HighestPC5 score was obtained in genotype 636965 under irrigated and stress conditions for ear height under stress conditions and thousand weight under both conditions. IC 623878 followed by IC 627708 had the highest PC score in PC6 for ear diameter and shelling % under irrigated conditions and IC 611611 had the highest score followed by IC 636965 for the number of kernels row^{-1} under stress conditions.

In PC1, the positive scores were in the range of 3.808 (BML-7) to 1.025 (BML-6) under irrigated conditions and from 3.801 (BML-7) to 1.283 (KML-109) under stress conditions. In PC2, the range of scores was from 3.177 (BML-6) to 1.963 (IC 611609) and from 2.575 (IC 636965) to 1.139 (IC 623880) under irrigated and stress conditions, respectively while in PC3, it was from 4.009 (IC 636977) to 1.023 (IC 611611) under irrigated and from 3.039 (IC 623875) to 1.497 (IC 623873) under stress conditions. In PC4, positive scores were between 3.03 (IC 623878) to 1.181 (IC 623879) and 2.849 (IC 627708) to 1.088 (KML-109) under irrigated and stress conditions, respectively. The low positive score was obtained in IC 627707 (2.264) and IC 623878 (1.022) under irrigated and stress conditions, respectively while genotype IC 636965 had a maximum score both under irrigated (2.451) and stress (2.737) under stress conditions. In PC6, positive values of the components ranged from 2.045 (IC 623878) to 1.02 (IC 623877) and 1.918 (IC 611611) to 1.10 (KML-109) under irrigated and stress conditions, respectively.

Genotypes IC 611609, IC 623878 and IC 636965 under irrigated conditions while, IC 611611, IC 623880, IC 636965 and KML-109 under stress conditions had maximum PC scores in at least two of the yieldrelated PC components. Two genotypes each in PC3 (IC 611611 and IC 636977), PC5 (IC 627707 and IC 636965) and one genotype in PC2 (IC 623880) had positive PC scores both in irrigated and stress conditions. Improvement for yield and yield related traits is possible by selecting lines from PC2 to PC6 more specifically IC 611611, IC 623880 and IC 636965 accessions are to be deployed in the development of elite maize breeding lines for irrigated and drought situations.

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