RESEARCH ARTICLE

Variability Studies in Maize (*Zea Mays* L.) Inbreds through Morpho Physiological Traits, Principal Component Analysis and their Relationship between Yield Components

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ABSTRACT

The presence of high genetic diversity in physiological traits among maize inbreds had scope for improving the inbreds for better canopy architecture. Eight maize inbreds were characterized by twelve morpho-physiological traits and four yield-related traits. Among the physiological traits, the photosynthetically active radiation (PAR) is evenly distributed in S38, S157, S289, and S322 inbreds at the canopy level. Leaf Dry Matter (LDM) had positive association (r = 0.734*) for 100 kernel weight. In Principal Component Analysis (PCA), the first two PCs were used to construct the biplot where the total number of kernels, cob girth, Average Growth Rate (AGR), and leaf dry matter had a positive association with S157, S322, and D164 inbreds. The inbred S157 recorded high leaf dry matter (47.55 g), more cob length (20.43 cm), more 100-kernel weight (39.32 g) and more average growth rate (6.18 g/day). Hence, S157 is considered as the best ideotype for the developing high yielding maize hybrids based on better canopy architecture.

Keywords: *Maize; Morpho-physiological traits; Descriptive statistics; PCA; Genetic diversity.*

INTRODUCTION

Maize is one of the major cereal and the third most important crop next to wheat and rice. The overall production of maize in the world was forecast at 1.07 million thousand tonnes in 2020. 28.5 million tonnes of maize produced by India in 2020. It was the sixth position in the world. (Knoema, 2020). The diversity of the genotypes is a key feature of the crop improvement programme. According to Tang *et al.,* (2018) increasing the productivity of maize was possible through high-density planting. Thus, we have to develop the high-density adapted varieties. Thereby, the inbreds having suitable plant architecture with uniform light distribution paves the way to select the inbreds for breeding programs. In maize cultivation, the environmental conditions and the genetic structure plays a dynamic role in yield. The energy from sunlight that was available to photosynthesis is photosynthetically active radiation (PAR). Available PAR to all stratum of crop canopy and utilizing it effectively plays a vital role in improving crop production (Wang *et al.,* 2004). Awal *et al.,* (2006) reported that improving the light use efficiency could improve the crop yield. Crop improvement mainly relies on genetic diversity. In germplasm identification, morphological characters were used earlier and it has an important role in classifying the genotypes (Shrestha, 2014). Nowadays many inbreds were selected from the restricted number of superior lines, which leads to reduce the diversity of germplasm on the commercially cultivating maize fields (Hallauer *et al.,* 1988).

Basic statistics like Mean, maximum, minimum, standard deviation, coefficient of variation (CV), and variance has been used to identify the variability pattern between inbreds (Sali *et al.,* 2013). Principal component analysis (PCA) is an algorithm that is used to upsurge the variance without affecting the data. It is a data analysis technique that helps in identifying the variance and similarities between inbreds and in categorizing the contribution of variables or traits towards genetic diversity. Many authors used PCA to estimate the genetic divergence and genetic variation for morphological traits in many crops *viz.,* maize, soybean, cowpea, cotton. Pearson's correlation coefficients between the variables used in the study to found the interrelationships between the variables (Iqbal *et al.,* 2015; Sali *et al.,* 2013). Understanding the genetic variability for morpho-physiological traits helps to develop the perfect ideotype and also utilization in a future breeding programme. The present study was aimed to characterize the maize inbreds with different canopy structures by assessing the morpho-physiological traits and yield-related traits.

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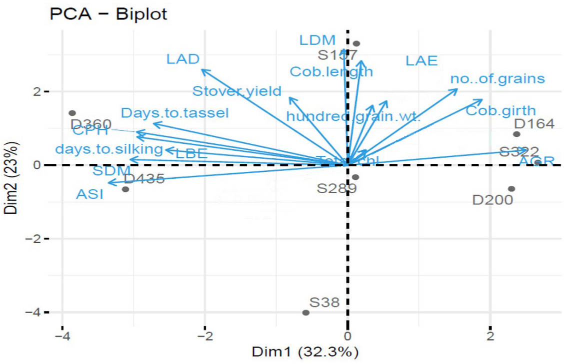
MATERIAL AND METHODS

The inbreds with different canopy structures were selected for the experiment. They were S38, S157, S289, S322, D164, D200, D360, and D435. Seed materials were collected from the Department of Plant Molecular Biology and Bioinformatics, Tamil Nadu Agricultural University, Coimbatore. Selected eight inbred lines were sown during Kharif 2020 in the Department of Farm Management, Tamil Nadu Agricultural University, Coimbatore. They were planted in a randomized complete block design (RCBD) with three replications. The field was maintained at sufficient field capacity by channel irrigation and the total recorded rainfall during the crop growth period was 332 mm, average maximum and minimum temperature was 31.44°C and 23.32°C respectively. Average relative humidity in the morning and afternoon was 83% and 57.2% respectively. The plant population was maintained at the rate of 11,111 plants/ha. NPK was applied at the rate of 135:62.5:50 kg of N: P: K per hectare. Other cultural practices were followed as per the university recommendation package.

Figure 1. Biplot showing variation between eight inbred lines along with 16 variables



In each replication three randomly selected plants were used for observing the morpho-physiological traits *viz.,* Anthesis silking interval (ASI), days to 50% tasselling (DT), days to 50% silking (DS), Shoot dry matter (SDM), leaf dry matter (LDM), leaves below the ear (LBE), leaves above the ear (LAE), cob placement height (CPH), cob length, cob girth, total number of kernels per ear, stover yield and 100 kernel weight.

Table 1. Descriptive statistics of Morpho-physiological traits of studied inbred lines

Traits	Mean	Maximum	Minimum	SD	Variance	CV %
LDM	31.10	50.66	19.71	7.65	58.52	24.60
SDM	100.01	147.91	72.51	22.22	493.54	22.22
DT	55.21	63.00	51.00	3.35	11.22	6.07
DS	56.96	66.00	51.00	4.01	16.04	7.04
ASI	1.71	4.00	0.00	0.95	0.91	55.56
LBE	5.88	8.00	4.00	1.12	1.25	19.05
LAE	5.71	6.00	5.00	0.46	0.22	8.06
CPH	78.46	110.50	65.50	13.19	173.85	16.81
LAD	88.92	104.72	61.01	10.44	108.97	11.74
AGR	4.51	7.25	1.65	1.78	3.17	39.47
Total chl	1.99	2.71	1.18	0.40	0.16	20.10
Stover yield	87.19	141.50	53.97	21.72	471.78	24.91
Cob length	17.44	21.20	14.10	1.89	3.58	10.84
Cob girth	14.89	16.60	12.90	1.15	1.31	7.72
100 grain wt	33.06	47.31	28.05	3.83	14.64	11.58
No of Kernels	500.13	724.00	331.00	86.46	7474.81	17.29

Total Chlorophyll content in leaves was estimated by using the DMSO method given by Hiscox *et.al,* (1979) and expressed in mg g^{-1} of fresh weight. Leaf area duration (LAD) was calculated as per the formula mentioned in Paul *et.al.* (2017) and expressed in cm^2 day. The average growth rate (AGR) was calculated as per the formula mentioned in Paul *et.al.* (2017) and expressed in g day^{-1}. Photosynthetically active radiation was measured above and below the crop canopy by the LI-190R quantum sensor (Licor, Lincoln, NE, USA) following the method mentioned by (Gao *et al.,* 2010) expressed in µmol of photons m^{-2} s^{-1}. A light sensor logger (LI 1500, Licor, Lincoln, NE, USA) was used to record the data.

The data were analysed using descriptive statistics, Principal component analysis (PCA) and Pearson's correlation coefficient to assess the genetic variance. Mean, maximum, minimum, standard deviation, coefficient of variation (CV), variance and analysis of variance (ANOVA) was carried out in SPSS Statistics version 16.0 (SPSS Inc., Chicago, Ill., USA). Principal component analysis (PCA) was performed by the software R version 3.3.2 and R Studio 1.0.136. Pearson's correlation coefficients between all traits used in the study were acquired to found the interrelationships between the traits.

RESULTS AND DISCUSSION

The morpho-physiological variations recorded among the inbreds were shown in Table 1. The basic statistics like mean, maximum, minimum, standard deviation (SD), variance, and coefficient of variation (CV) were calculated for all the variables. Higher variability was found in ASI (55.6%) followed by AGR (39.47%), stover yield (24.91%) and LDM (24.6%). The lower variability was found in DT (6.07%) followed by DS (7.04%) cob girth (7.72%) and LAE (8.06%).

Table 2. *Per se* performance of morpho-physiological parameters.

Inbred lines	Cob length (cm)	Cob girth (cm)	100 grain weight (g)	Total no. of kernels	Stover yield (g)	PAR decrease %	LAD (cm^2 day)	AGR (g day^{-1})
S38	14.7 ± 0.25d	13.1 ± 0.13c	32.73 ± 0.65b	375.0 ± 33.61b	90.18 ± 9.3ab	76.3 ± 2.06f	67.6 ± 3.6c	5.06 ± 0.05b
S157	20.4 ±0.30a	15.0 ± 0.23b	39.32 ± 0.89a	499.6 ± 34.57ab	119.18 ± 11.6a	89.6 ± 0.09cd	92.6 ± 3.3ab	6.18 ± 0.24a
S289	16.2 ± 0.39cd	15.8 ± 0.26ab	32.48 ± 0.47b	519.3 ± 45.08ab	76.81 ± 5.7b	88 ± 1.06de	88.0 ± 1.7b	4.28 ± 0.35c
S322	17.5 ± 0.45bc	15.0 ± 0.28b	31.03 ± 0.21b	507.7 ± 20.95ab	78.79 ± 4.5ab	86.1 ± 0.67e	100.6 ± 2.6a	2.43 ± 0.08e
D164	17.9 ± 0.34bc	15.6 ± 0.17ab	32.02 ± 0.67b	594.7 ± 65.10a	89.33 ± 17.4ab	94.6 ± 0.98a	95.1 ± 4.4ab	3.27 ± 0.04d
D200	17.3 ± 0.42bc	16.2 ± 0.22a	33.61 ± 0.34b	527.7 ± 33.20a	68.81 ± 6.7b	93.3 ± 0.54ab	89.5 ± 2.0b	1.92 ± 0.14e
D360	16.8 ± 0.35bcd	14.97 ± 0.27b	30.98 ± 0.54b	482.3 ± 34.28ab	90.31 ± 12.5ab	91.4 ± 1.1bc	93.6 ± 2.9ab	6.39 ± 0.20a
D435	18.6 ± 0.32ab	13.43 ± 0.28c	32.31 ± 0.31b	494.7 ± 65.42ab	84.11 ± 15.4ab	92.6 ± 0.89ab	84.4 ± 3.1b	6.59 ± 0.35a

* Mean ± SE values (n=3) with different alphabets were significantly different at ($P<0.05$) level

This variability between the morpho-physiological traits was found similar to the studies of Iqbal *et al.* (2015); Shrestha, (2014). A significant difference was found among the inbreds for all the variables studied (Table 2 & Table 3). Variability among the inbred lines was mainly due to genetic as well as environmental factors. The photosynthetically active radiation (PAR) decrease percentage, which indicates the amount of PAR reduced while passing through the canopy to reach the soil surface. The amount of reduced percentage was more in D164 followed by D200. S38 recorded with a lower reducing percentage (Table 2). The droopiness of leaves reduces the amount of PAR to reach the surface of the soil. The result of study was in accordance with the findings of Pepper *et al.* (1977) and Liu *et al.* (2011).

The character's association between inbreds is presented in Table 4. LDM was positively correlated with stover yield (r = 0.800*), cob length (r = 0.828*) and 100 grain yield (r = 0.734*). Per se performance of LDM and 100 kernel weight were recorded more in S157 (Table 2). The average growth rate (AGR) was indicating the growth of the plant per unit time. Per se performance of the AGR at post silking stage recorded more in D360 followed by D435 (Table 2). Also, LDM was recorded less than the SDM for the two inbreds, respectively. This result is in accordance with Machado *et al.* (2015).

SDM and ASI were positively correlated (r= 0.778*) which leads to reducing yield. ASI also negatively correlated with yield attributes like cob length (r = -0.204), cob girth (r = -0.488), total number of kernels per cob (r = -0.433) and 100 grain weight (r = -0.213). Similar results accorded by Edmeades and Islam (1987). Anthesis silking interval was counted more in D360 followed by D435 (Table 3). CPH was positively correlated with SDM (r = 0.708*). CPH increased the plant height thereby increasing the SDM which is in accordance with Shrestha (2014), in this study, the per se performance of D360 and S38 recorded the high and low CPH respectively (Table 2). LAE was positively correlated to the cob length (r = 0.309), cob girth (r= 0.829*), total number of kernels (r= 0.633) 100 grain weight (r= 0.108). Where, LBE was negatively correlated to the cob girth (r= -0.317), total number of kernels (r= -0.488) and 100 grain weight (r= -0.318). *Per se* performance of the LBE was more and less in D435 and S38 respectively. Kefu *et al.* (1981) stated that LAE were contributed more to photosynthesis thus indirectly favour the yield.

Principal component analysis (PCA) is a technique that is used to reduce the complexity of variables to a smaller set of uncorrelated variables without affecting the original data. It was used to visualize the multi-dimensional and to identify the underlying variables. In maize, many authors used PCA to find the divergence among inbred lines (Mishra, 2016). In the present study Principal component analysis (PCA) was performed for 16 morpho-physiological and yield related traits of eight inbred lines. PCA sorted out the total variables into eight main principal components (PCs) (PC1 to PC8) in which the first principal component 1(PC1) contributes 32.3% and the last PC8 contributes almost nil. Among the eight PCs first six PCs showed more than one eigen value and their cumulative contribution towards the variation is 98.4% among the inbred lines. According to Walle *et al.,* (2019) Eigen values should be more than one for PCs to contributing significant variation towards genetic diversity.

Table 3. *Per se* performance of morpho-physiological parameters

Inbred lines	ASI (Days)	DT (Days)	DS (Days)	LBE	LAE	LDM (g)	SDM (g)	CPH (cm)
S38	2.0 ± 0.58bc	53.3 ± 0.67d	55.7 ± 1.33c	5.0 ± 0.00cd	5.0 ± 0.00b	21.72 ± 1.19d	107.36 ± 1.21c	68.33 ± 1.83c
S157	1.3 ± 0.33cde	55.0 ± 0.00bc	56.3 ± 0.33bc	5.3 ± 0.33bcd	6.0 ± 0.00a	47.55 ± 1.59a	111.94 ± 5.03bc	74.17 ± 1.74c
S289	1.7 ± 0.33cd	56.3 ± 0.33b	58.0 ± 0.00b	5.3 ± 0.33bcd	6.0 ± 0.00a	28.63 ± 1.07c	85.10 ± 3.31d	72.33 ± 2.05c
S322	0.7 ± 0.33e	51.0 ± 0.00e	51.7 ± 0.33d	6.0 ± 0.00b	6.0 ± 0.00a	27.45 ± 1.40c	84.97 ± 1.92d	72.17 ± 0.93c
D164	1.0 ± 0.00de	54.0 ± 1.00cd	55.0 ± 1.03c	4.7 ± 0.33d	6.0 ± 0.00a	34.80 ± 1.60b	79.70 ± 1.28de	69.17 ± 1.92c
D200	1.3 ± 0.33cde	53.7 ± 0.33cd	55.0 ± 0.03c	5.7 ± 0.33bc	5.7 ± 0.33a	27.16 ± 0.86c	73.46 ± 0.75e	72.17 ± 1.01c
D360	3.0 ± 0.00a	62.7 ± 0.33a	65.7 ± 0.33a	7.3 ± 0.33a	6.0 ± 0.00a	33.29 ± 1.25b	118.70 ± 4.15b	105.17 ± 2.73a
D435	2.7 ± 0.67ab	55.7 ± 0.33b	58.3 ± 0.33b	7.7 ± 0.33a	5.0 ± 0.00b	28.18 ± 1.48c	138.86 ± 4.52a	94.17 ± 0.88b

± SE values (n=3) with different alphabets were significantly different at ($P<0.05$) level

According to Walle *et al.* (2019) the factor score should above ±0.3 said to be significantly contributing either positively or negatively to the divergence. PC1 contributes 32.3% in total variation in which ASI (-0.39), SDM (-0.355), CPH (-0.344) and DS (-0.317) were negatively and significantly contributed more for PC1. PC2 gives 23% variation in total variation in which LDM (0.434), LAD (0.338), Cob length (0.391) and LAE (0.352) were positively and significantly contributed more for PC2. PC3 contributes 17% in total variation in which stover yield (0.383) and 100-grain weight (0.412) were significantly contributed more for PC3.

In the present study, the biplot of PCA (Figure 1) showed that D200, S322, D164 were scattered close to each other. It showed less diversity among them and they had similar profiles. The inbreds S157, S38, D360 were laid far away from each other and they said to be more diverse.

Table 4. Correlation among the morpho-physiological and biochemical traits for studied maize

	CPH	LDM	SDM	LAD	AGR	Stover yield	Cob length	Cob girth	No of grains	100 grain wt	Total chl	DT	DS	ASI	LBE	LAE
CPH	1															
LDM	0.089	1														
SDM	0.707*	0.143	1													
LAD	0.778*	0.58	0.517	1												
AGR	-0.354	-0.036	-0.506	-0.272	1											
Stover yield	0.056	.800*	0.448	0.335	-0.319	1										
Cob length	0.122	.828*	0.223	0.556	0.323	0.558	1									
Cob girth	-0.232	0.313	-.748*	0.14	0.36	-0.249	0.209	1								
No of grains	-0.088	0.395	-0.465	0.289	0.463	-0.155	0.506	.758*	1							
100 grain wt	-0.27	.734*	0.117	0.11	-0.034	.734*	0.639	0.076	-0.026	1						
Total chl	0.208	-0.02	-0.042	0.049	0.342	0.059	-0.077	-0.068	-0.109	-0.34	1					
DT	.821*	0.233	0.464	.717*	-0.652	0.164	-0.036	0.039	-0.046	-0.129	0.026	1				
DS	.846**	0.15	0.544	0.672	-0.694	0.148	-0.095	-0.083	-0.151	-0.155	0.006	.991**	1			
ASI	.838**	-0.141	.778*	0.468	-0.688	0.052	-0.204	-0.488	-0.437*	-0.213	-0.108	.795*	.869**	1		
LBE	.904**	-0.105	0.693	0.654	-0.098	-0.146	0.156	-0.317	-0.111	-0.318	0.165	0.529	0.574	.712*	1	
LAE	-0.086	0.55	-0.532	0.38	0.192	0.118	0.309	.829*	0.633	0.108	0.262	0.173	0.04	-0.447	-0.262	1

Anthesis silking interval (ASI), days to 50% tasseling (DT), days to 50% silking (DS), Shoot dry matter (SDM), leaf dry matter (LDM), leaves below the ear (LBE), leaves above the ear (LAE), cob placement height (CPH), Leaf area duration (LAD) and Average growth rate (AGR)

* - Correlation is significant at the 0.05 level (2-tailed).

** - Correlation is significant at the 0.01 level (2-tailed).

The biplot was constructed based on the first two PCs and previously Vijayakumar *et al.,* (2020) constructed a PC biplot with a similar method. In the present study S157, S322 and D164 had performed well and located in the first quadrant, and the least performed S38, D435 located in the third quadrant. Inbreds located in the first quadrant (labelled in roman) performed well compare to the other quadrants. Inbreds located in the third quadrant (label) performed least compare to the other quadrants. Both PCs had negative scores (Tamilselvi *et al.,* 2015). The total number of kernels, cob girth, LAE, AGR, and LDM had a positive association with S157, S322, and D164. ASI and SDM had a negative association with these inbreds. The total number of kernels, cob girth, LAE, AGR, and LDM had a negative association with S38 and D435. ASI and SDM had a positive association with the inbreds. Variables positioned opposite sides of the plot in diagonally opposite quadrants are said to be negatively correlated. Two variables positioned in the same quadrant were positively correlated. Variables positioned near to the origin had a lower loading factor which had less contribution towards diversity. Variables away from the origin had a higher loading factor which had more contribution towards diversity (Vijayakumar *et al.,* 2020).

CONCLUSION

The present study conferred that the diversity among inbreds with different canopy structures was existing for various morpho-physiological traits. The genotypes with more PAR distribution had a positive association with yield-related traits. This variation could be used to develop the perfect ideotypes with high yielding potential. Leaf dry matter has more correlation with the yield attributes than the shoot dry matter. Leaves above the ear had a positive association with yield attributes than the leaves below the ear. The best performing genotypes (S157, S322) and least performing genotypes (D435, S38) for the given variables were determined by using PCA. This will be useful in eradicating the duplicated genotypes thereby conserving and increasing the diversity in maize breeding programs. The selected inbreds could further be utilized for developing new varieties in maize breeding plans.

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