



Performance of Six Maize Genotypes under High Temperature based on Grain Yield Traits

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ABSTRACT: High temperature conditions negatively affect maize plants development leading to loss in grain yield. Therefore, this study was conducted to evaluate response of high temperature on the basis of yield performance and its components of six maize genotypes in order to find tolerant genotypes under high temperature conditions. The study was carried out in a randomized complete block design (RCBD) with three repetitions, to assess, Plant height, green leaves no., leaf length, leaf width, leaf area, dry leaves no., ear distance from earth, ear length, ear diameter, ear rows, ear weight, ear grains weight, weight of 100 grains and grain yield/plant. The findings indicated that there was significant genetic variation among the studied genotypes. According to Pearson correlation coefficient, heatmap and principal component analysis, the leaf width, leaf area, ear length, ear diameter, ear rows, ear weight and ear grain weight had positive correlation with grain yield. Consequently, these traits can be chosen as a best trait to improve maize grain yield under heat stress conditions. In addition, genotypes G-70, G-71 and G-76 were found to be tolerant to heat stress due to their high values traits that positive correlated to grain yield potential as approved by cluster analysis that showed that these genotypes cluster together in group (B). Considering that these genotypes could be useful in developing heat tolerant varieties as a parental material in breeding programs.

Keywords: Maize (*Zea mays* L.), high temperature, yield traits, Pearson correlation, heatmap analysis, PCA, phylogenetic tree.

INTRODUCTION

In the summer, maize (*Zea mays* L.) considers an essential cereal crop due to its utilization in human, animal and poultry feed to overcome lack of wheat production (Molazem, 2022; Yawale *et al.*, 2023). Compared to wheat and rice, maize is more vulnerable to high temperature (Dong *et al.*, 2021; Rashid *et al.*, 2023).

High temperature leads to excess of reactive oxygen species results inhibition in both vegetative and reproduction stages of maize plants (El-Sappah *et al.*, 2022; Himania *et al.*, 2022). When temperature rise above 35°C during pollen-shedding period, anthesis and silking are severely affected leading to extremely poor pollination and barren ears leading to low yield potential (Hussain *et al.*, 2019; Zhang *et al.*, 2020). Under high temperature, grain yield decreases due to general decrease in leaf area and elongation that affect photosynthetic activity and shoot biomasses (Hassaan, 2018; Divya *et al.*, 2019).

Akbari *et al.* (2015) also found significant difference among plant height in maize. Seyedzavar *et al.* (2015) also found positive correlation between grain yield and ear height in corn under water deficit stress.

Climate change is reported to loss of agricultural production the most, with severe effects of high temperature, challenging researchers toward developing strategies to counter stress (Singh *et al.*, 2022).

Exposure to heat stress at reproductive stage resulted in reduction in the number of productive tillers, number of filled grains and unfilled grains, panicle length, MSI, total dry matter and harvest index and increase in number of unfilled grains (Nandhini *et al.*, 2023).

Therefore, this study was conducted to evaluate response of high temperature on the basis of yield performance and its components of six maize genotypes in order to find tolerant genotypes under high temperature conditions.

MATERIALS AND METHODS

In the summer 2023, the yield performance of six maize genotypes (G-70, G-71, G-339, G-76, G-5 and G-44-2) under high temperature conditions and sandy load soil was assessed using randomized complete block design (RCBD) at Elkawther Research Farm., Faculty of Agric., Sohag Univ., Sohag, Egypt during summer season 2023. To prevent potential negative effects of soil disease, grains were treated with fungicide. Fertilizers (nitrogen, phosphorus and potassium) were added according to appropriate doses. Before planting 200 kg/fed of phosphorus fertilizer (calcium super phosphate (15.5% P₂O₅)) was used in single dosage, and at the same time 50 kg/fed of potassium fertilizer (potassium sulphate (48% K₂O)) was added. After that, eight equal doses of nitrogen fertilizer (ammonium sulphate (20.6% N)) were applied at level of 600 kg/fed, the first dose was given seven days after planting, and the last dose was given prior the flowering stage.

Sowing was started in 9 May 2023 with the aid of dibbler to sow in three rows of three meters with 50-centimeter gap between rows and 20 centimeters between plants with each row. One plant per hill was thinned once the crop reached a height of 15-centimeter (three leaf stage). To guarantee healthy plant stand, all agricultural techniques were used.

Once the ears reached maturity and the grains moisture content were less than 30%, ten randomly selected samples were collected to record morphological, phenological and grain yield traits as follow:

- 1) Plant height (cm), were taken by rubber from soil surface to of leaf flag base.
- 2) Ear Distance from Earth (cm), were taken by rubber from soil surface to the base of lowest ear.
- 3) Green Leaves (No.), were taken by counting green leaves number.
- 4) Dry Leaves (No.), were taken by counting dry leaves number.
- 5) Leaf Width (cm), were taken by rubber.
- 6) Leaf Length (cm), were taken by rubber.
- 7) Leaf Area= leaf length × maximum leaf width × 0.74 (Anne Elings, 2000).
- 8) Ear length (cm), were taken by rubber.
- 9) Ear Diameter (cm), were taken by rubber.
- 10) Ear Rows (No.), were taken by counting rows of each ear.
- 11) Ear Weight (gm), were taken by weighting selected five ears in each replication randomly.
- 12) Ear grains weight (gm), were taken by weighting grains of each ear in micro analytical digital balance.
- 13) Weight of 100 Grains (grain index) (gm), were taken by weighting random 100 grains and weighted in micro analytical digital balance.
- 14) Grain Yield/plant (gm), were taken by weighting all grains from all ears in each plant in micro analytical digital balance.

After tabulating and processing the data in Microsoft Excel 2016, mean sum squares and correlation

coefficient were used to assess significant differences between genotypes and traits according to Snedecor and Cochran (1980); Steel *et al.* (1997). Statistical software program (NCSS-24) was utilized for cluster analysis (Euclidean Method) to classify genotypes according to their response to high temperature. To calculate association between traits principal component analysis (PCA) and Scree Plot analysis were computed according to (Sneath and Sokal 1973) by statistical software program (SPSS-9).

RESULTS

Mean sum squares resulting from genotypes were highly significant for all traits as mentioned in Table 1, indicating genetic variability controlled by dominant genes between genotypes which will be useful as a favorable source of alleles for maize genotypes improvement.

According to mean performance (Fig. 1), the maximum values of plant height, ear distance from earth, green leaves no., and leaf length were displayed in genotype G-44-2. However, the genotype G-70 performed well in terms of ear length, ear diameter and ear row. On the other hand, G-71 shown superior performance in dry leaves no., ear length, ear diameter, ear weight, ear grains weight, weight of 100 grains and grain yield. Furthermore, the genotypes G-5 and G-339 shown excellent performance in terms of leaf length and dry leaves no., respectively. In the same manner, the genotype G-76 performed significantly in terms of green leaves no., leaf width, leaf area, ear length and grain yield. Demonstrating that the high performed genotypes were tolerance to high temperature during flowering and filling phases.

To detect the relationship between grain yield and its components Pearson correlation coefficient were computed by elaborating degree of association among traits as showed in Table 2 and Fig. 2, the finding showed significant positive correlation between green leaves no and plant height, ear distance from earth, leaf width and leaf area. Likewise, significant positive correlation was found between leaf width, leaf area, ear length, ear diameter, ear weight, ear grains weight and grain yield. Moreover, ear length and ear diameter were significantly positive correlated with ear rows, ear weight, ear grains weight, weight of 100 grains and grain yield. In addition, plant height and ear distance from earth were significantly positive correlated with ear rows. Conversely, there was significant negative correlation between dry leaves no. and plant height, leaf area, ear distance from earth and green leaves no.

To evaluate the contribution between genotypes and traits, heatmap analysis were computed using (Euclidean Method) as presented in Table 3 and Fig. 3. The findings showed three clusters; In cluster-1 the genotypes G-70 and G-71 performed well in ear diameter, ear rows, green leaves no., dry leaves no., ear weight, ear grains weight, leaf width, weight of 100 grains, ear length and grain yield. In cluster-2, genotypes G-339, G-5 and G-44-2

showed high performance in plant height, ear distance from earth, green leaves no., dry leaves no., leaf length. While, in cluster-3, genotype G-76 performed well in green leaves no., leaf width, leaf area, ear length and grain yield. Indicating that, studied genotypes had distinct response toward high temperature.

To assess and classify genotypes according to yield performance and its components, principal components analysis (Table 4 and 5) was computed five plots (PC1, PC2, PC3, PC4 and PC5). According to scree plot (Fig. 4), PC1, PC2, PC3, PC4 and PC5 represented 90.14%, 6.94%, 2.73%, 0.14% and 0.05% variations in all traits, respectively, confirming genetic variation toward high temperature. PC1 presented significant variation between genotypes in leaf area, leaf width, ear rows, ear weight, ear grains weight, weight of 100 grains and grain yield. Meanwhile, PC2 demonstrated significant variation between genotypes in green leaves no., dry leaves no., and ear distance from earth. On the other hand, PC3 showed significant variation between

genotypes in plant height. Furthermore, PC4 exhibited significant variation between genotypes in leaf length. Whereas, PC5 noted significant variation between genotypes in ear diameter. The scatter analysis (Fig. 5) showed variation among genotypes along PC1 and PC2 axes. The findings demonstrated strong association between G-339, G-5 and G-44-2. However, genotypes G-70 and G-71 were associated to one another. Conversely, genotype G-76 were distinct solely as affirmed by heatmap analysis. As a result, these traits might be used as a selection-criteria for maize breeding programs under high temperature conditions.

Phylogenetic tree by Euclidean Method (Fig. 6) were used to confirm genotypes performance toward high temperature conditions. In group (A), the genotypes G-339 and G-5 were clustered together with genotype G-44-2. In contrast, the genotypes G-70 and G-71 were clustered together with genotype G-76 in group (B). Indicating that the genotypes in the same group have the same performance toward high temperature conditions.

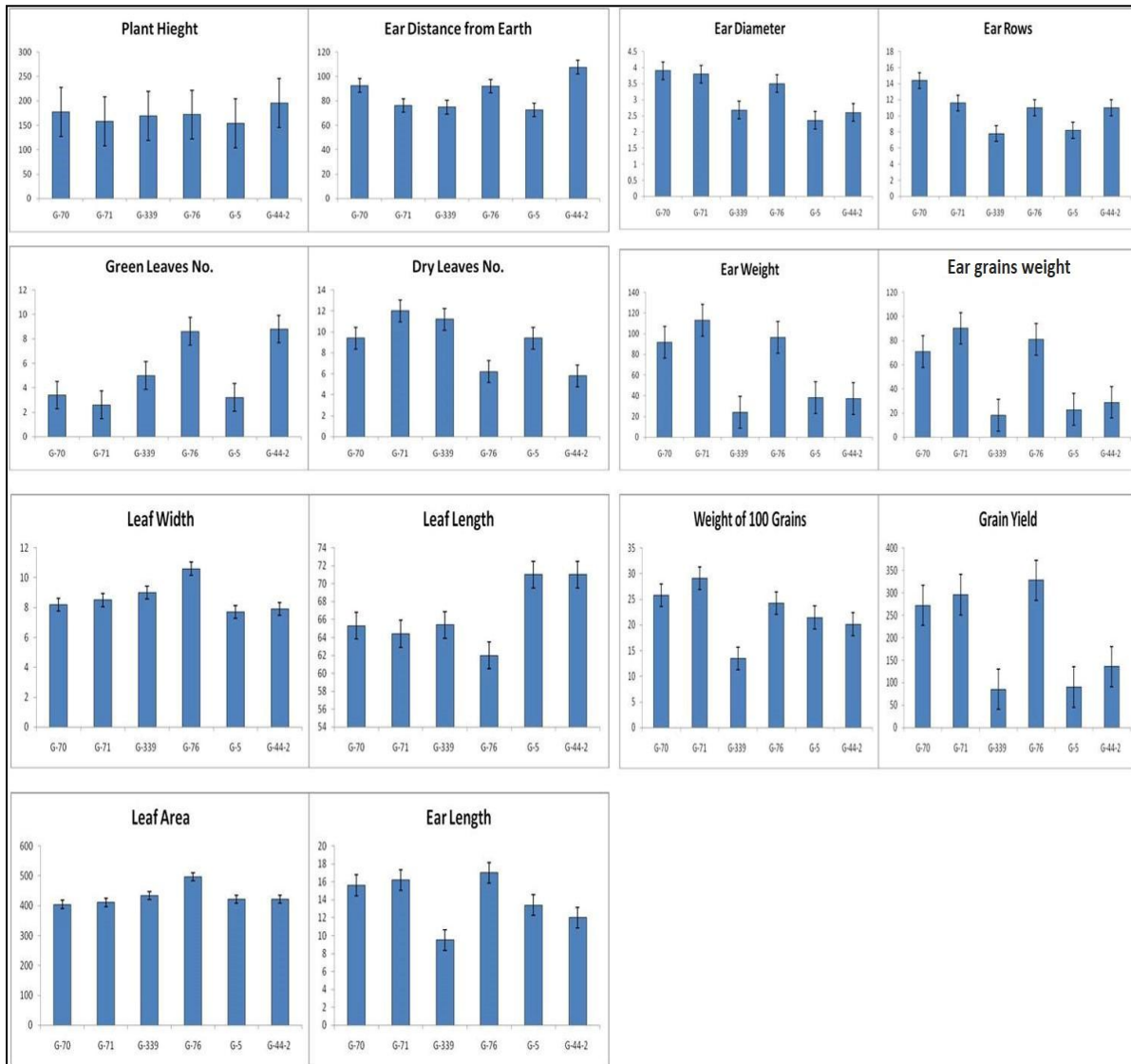


Fig. 1. Mean performance of six maize genotypes on traits under high temperature conditions during summer season 2023 (Bars represent standard error of the means).

Table 1: Mean sum squares yield and its components in six maize genotypes under high temperature conditions during summer season 2023.

		Plant height	Ear distance from earth	Green leaves no.	Dry leaves no.
S. O. V	D.F.	Mean square	Mean square	Mean square	Mean square
Genotypes	5	656.49**	568.29**	23.12**	19.34**
Error	12	43861.50	11085.40	41.61	121.50
		Leaf width	Leaf length	Leaf area	Ear length
S. O. V	D.F.	Mean square	Mean square	Mean square	Mean square
Genotypes	5	3.37**	40.69**	3389.24**	24.59**
Error	12	112.23	6636.70	279607.80	291.90
		Ear diameter	Ear rows	Ear weight	Ear grains weight
S. O. V	D.F.	Mean square	Mean square	Mean square	Mean square
Genotypes	5	1.35**	17.60**	4296.38**	3114.04**
Error	12	14.79	170.67	6689.35	4064.85
		Weight of 100 grains	Grain yield		
S. O. V	D.F.	Mean square	Mean square		
Genotypes	5	87.47**	36081.82**		
Error	12	749.84	60762.41		

D.F. (Degrees of Freedom), *(Significant at 5% probability level), ** (Significant at 1% probability level).

Table 2: Pearson correlation coefficient for traits in six maize genotypes under high temperature conditions during summer season 2023.

	Plant height	Ear distance from earth	Green leaves no.	Dry leaves no.	Leaf width	Leaf length	Leaf area	Ear length	Ear diameter	Ear rows	Grain yield/plant	Ear weight	Ear grains weight	Weight of 100 grains
Plant height	1													
Ear distance from earth	0.93*	1												
Green leaves no.	0.72*	0.74**	1											
Dry leaves no.	-0.68*	-0.82**	-0.87**	1										
Leaf width	-0.02	0.04	0.47*	-0.25	1									
Leaf length	0.18	0.14	-0.005	-0.19	0.82*	1								
Leaf area	0.03	0.13	0.66**	-0.52*	0.90*	0.49*	1							
Ear length	-0.21	0.11	-0.09	-0.14	0.35*	0.51*	0.25	1						
Ear diameter	-0.05	0.10	-0.23	0.19	0.35*	0.76*	0.004	0.77*	1					
Ear rows	0.38*	0.54*	-0.04	-0.16	-0.01	0.32*	-0.21	0.66*	0.82**	1				
Grain yield/plant	-0.01	0.22	0.04	-0.09	0.54*	0.75*	0.31*	0.91*	0.92**	0.74**	1			
Ear weight	-0.19	0.04	-0.20	0.12	0.37*	0.68*	0.12	0.92*	0.93**	0.72**	0.96**	1		
Ear grains weight	-0.14	0.09	-0.12	0.07	0.44*	0.73*	0.18	0.91*	0.93**	0.71**	0.98**	0.99*	1	
Weight of 100 grains	-0.21	0.09	-0.29	0.05	0.01	-0.31*	-0.12	0.92*	0.76**	0.72**	0.81**	0.90*	0.87**	1

*Significant at 5% probability level, ** Significant at 1% probability level,

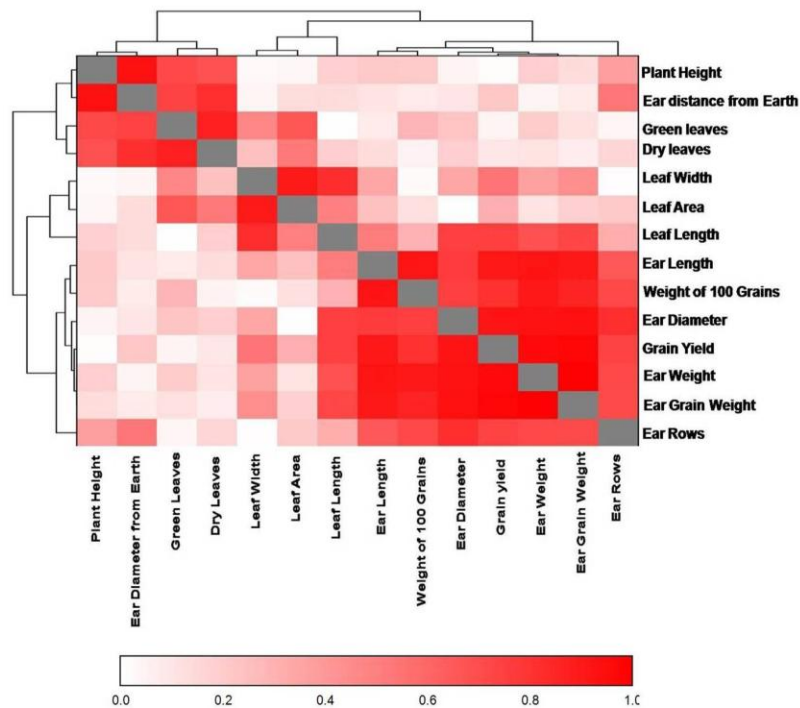


Fig. 2. Cluster analysis of Pearson correlation coefficient for traits in six maize genotypes under high temperature conditions during summer season 2023.

Table 3: Contribution between genotypes and traits under high temperature conditions during summer season 2023.

Cluster	Traits
G-70 and G-71	Ear diameter, Ear rows, Green leaves no., Dry leaves no., Ear weight, Ear grains weight, Leaf width, weight of 100 grains, Ear length and Grain yield
G-339, G-5 and G-44-2	Plant height, Ear distance from earth, Green leaves no., Dry leaves no., Leaf length
G-76	Green leaves no., Leaf width, Leaf area, Ear length and Grain yield

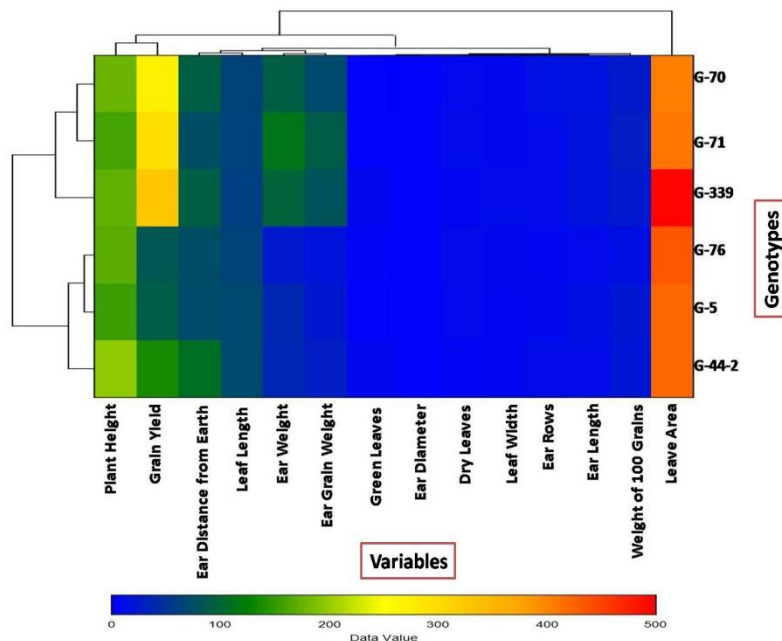


Fig. 3. Cluster analysis of contribution between genotypes and traits under high temperature conditions during summer season 2023.

Table 4: Contribution of five plots (PC1, PC2, PC3, PC4 and PC5) in genetic variation for six maize genotypes under high temperature conditions during summer season 2023.

Sr. No.	Genotypes	PC 1	PC 2	PC 3	PC 4	PC 5
1.	G-70	75.13	-31.83	14.19	-2.94	-4.10
2.	G-71	108.73	-35.71	-15.52	0.64	3.69
3.	G-339	-128.14	13.26	-8.96	-7.64	1.00
4.	G-76	137.92	55.68	-3.19	0.83	-0.50
5.	G-5	-118.51	-4.32	-21.32	5.90	-2.25
6.	G-44-2	-75.13	2.92	34.79	3.21	2.16

Table 5: Contribution of five plots (PC1, PC2, PC3, PC4 and PC5) in genetic variation for yield and its components traits under high temperature conditions during summer season 2023.

PC 1	PC 2	PC 3	PC 4	PC 5
Leaf width	Green leaves no.	Plant height	Leaf length	Ear diameter
Leaf area	Dry leaves no.			
Ear rows	Ear distance from earth			
Weight of 100 grains				
Ear weight				
Ear grains weight				
Grain yield				

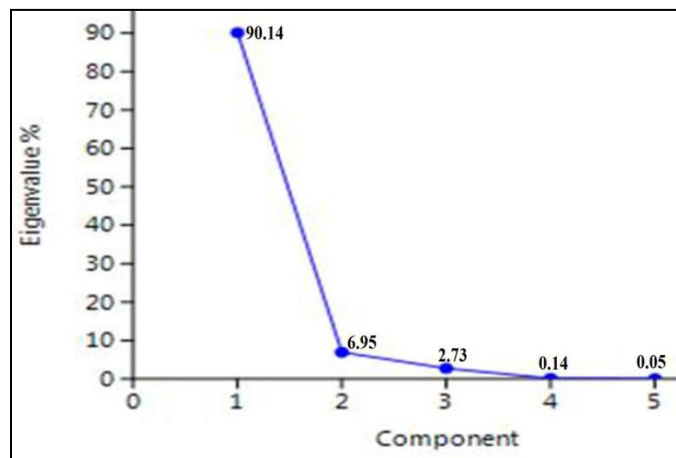


Fig. 4. Scree plot principal components for (PC1) and Eigenvalue % (PC2) for six maize genotypes under high temperature conditions during summer season 2023.

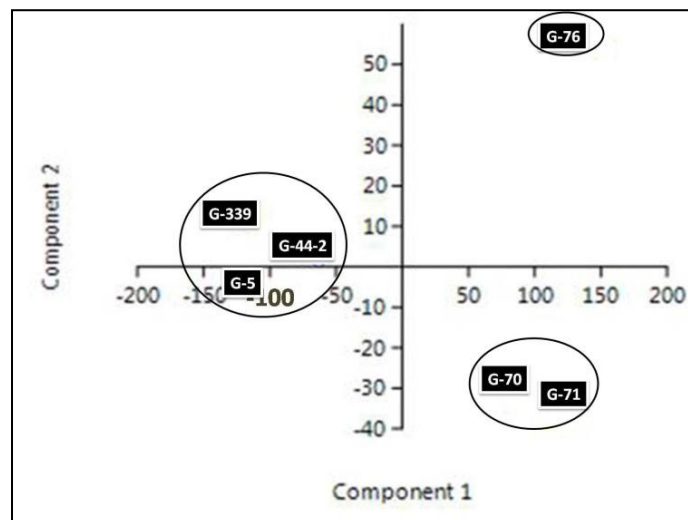


Fig. 5. Scatter plot for principal components (PC1) and Eigenvalue % (PC2) for six maize genotypes under high temperature conditions during summer season 2023.

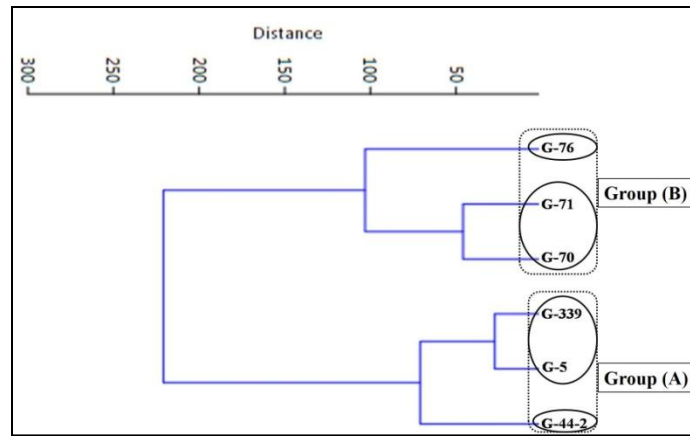


Fig. 6. Phylogenetic tree by Euclidean Method for six maize genotypes under high temperature conditions during summer season 2023.

DISCUSSION

There are numerous of physiological and biochemical changes brought by high temperature such as poor anthesis and silking which suppress maize ovary fertilization and grain filling process resulting reduction in seed size and numbers that leading to reduction in grain yield (Hussain *et al.*, 2019; Zhang *et al.*, 2020; Chukwudi *et al.*, 2021). Understanding many traits especially those linked to grain yield is the major goal of maize breeding programs. So, it is important to find genotype that exhibit stability under high temperature conditions. Therefore, the aim of this study is to evaluate response of high temperature on the basis of yield performance and its components of six maize genotypes in order to find tolerant genotypes under high temperature conditions.

The results showed significant differences for all traits, indicating genetic variability among genotypes as mentioned by Trachsel *et al.* (2016) who noted significant genotype and environment on maize grain yield under high temperature conditions. Shehzad *et al.* (2019); Cheema *et al.* (2020) also demonstrating significant variation among maize genotypes in grain yield and its components under high temperature conditions. Furthermore, genotypes G-70, G-71 and G-76 exhibited superior performance in grain yield and its components, indicating that these genotypes may share genetic factors that improve yield production under high temperature conditions, so these genotypes can be used as a parental source of high temperature tolerance in maize breeding programs as mentioned by Baiyeri *et al.* (2019); Belay and Adare (2020); Krishnaji *et al.*, 2020; Inyang *et al.*, (2021).

Because of grain yield is a complex trait and influenced by several components, understanding interrelationship of them can significantly enhance the efficiency of maize breeding programs. Yang *et al.* (2020) found that high temperature decreases dry matter accumulation, ear grains, grain weight and grain yield. In addition, Shrestha (2016); Divya (2019) reported that grain yield

reduction is correlated with low pollen viability under high temperature conditions. Moreover, traits that significant positive correlated with grain yield can be selected as a superior trait under high temperature conditions in maize breeding programs as confirmed by Yousaf *et al.* (2017) who found significant positive correlation under high temperature conditions between grain yield and ear grains and 100 grain weight. Similar findings demonstrating correlation between grain yield and plant height (Chen *et al.*, 2012) and between grain yield and ear distance from earth (Shrestha *et al.*, 2014). Also, the findings were supported by principal component analysis (PCA) by identifying varied traits under high temperature conditions. In this study the main varied traits were leaf area, leaf width, ear rows, ear weight, ear grains weight, weight of 100 grains and grain yield. As a result, these traits might be used as selection criteria to enhance maize plants under high temperature conditions.

CONCLUSIONS

Genotypes G-70, G-71 and G-76 exhibited superior performance in grain yield and its components, indicating that these genotypes may share genetic factors that improve yield production under high temperature conditions, so these genotypes can be used as a parental source of high temperature tolerance in maize breeding programs. In addition, leaf area, leaf width, ear rows, ear weight, ear grains weight, weight of 100 grains and grain yield were considered main varied traits which may be used as a selection criterion to enhance maize plants under high temperature conditions.

FUTURE SCOPE

Breeding and genetic techniques e.g., GWAS are required to facilitate processes of genetic improvement.

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Conflicts of Interest. None.

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