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Evaluation of Bi-Parental Mating System out Puts in Two Crosses for Drought Tolerance in Egyptian Cotton (*Gossipum Barbadense* L.)

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Abstract: In order to study the response of twelve of Egyptian cotton genotypes to drought stress, a field experiment was conducted in a split plot design with randomized complete blocks (RCB) arrangement with three replications under irrigated and water stress conditions during a successive growing seasons 2018. The estimates of stress tolerance attributes indicated that the identification of drought-tolerant genotypes based on a single criterion was contradictory. Result of correlation analysis between yield and its component in both conditions and calculated drought resistance indices revealed that stress tolerance index (STI), mean productivity (MP), geometric mean productivity (GMP), harmonic mean (HM), yield index (YI), Yield stability index (YSI) and drought resistance index (DI) were the best indices for identifying high yielding genotypes for seed cotton yield and lint cotton yield in both conditions (drought tolerant genotypes). Therefore, these indices could be used successfully as selection criteria for the screening of genotypes for performance under various soil moisture levels. Screening drought tolerant genotypes using mean rank, standard deviation of ranks and rank sum (RS) distinguished G4 and G5 as the most drought tolerant genotypes. Cluster analysis showed that the genotypes, based on indices tended to group into three groups: tolerant, semi- tolerant and sensitive genotypes. Principal component analysis (PCA), indicated that first and second components justified 99.82% and 99.858% variations for seed cotton yield and lint cotton yield, respectively among drought tolerance indices.

Keywords: *Egyptian cotton (Gossipum barbadense L.), seed cotton yield, drought tolerance indices, ranking method, principal component analysis, clusters analysis.*

INTRODUCTION

Cotton is considered as world commercial crop. The development of novel, high-yielding, stress-tolerant varieties of cotton with adequate fiber quality characteristics are among the major goals of cotton breeders in cotton breeding programs. The first step to achieve that is choosing suitable parents for generating promising genotypes with higher heterosis (Hussain, *et al.*, 2019). As cotton is grown in warm climates, production occurs in more than 80 countries, and cotton is an economic crop in more than 30 of these countries. With rapidly increasing world population and climate change, abiotic and biotic pressures represent the major challenges in crop production worldwide. So it is necessary to increase crop yields by at least 40% in arid and semi-arid regions (Nakashima, *et al.*, 2014; Shaar-Moshe, *et al.*, 2017). Therefore, crop varieties should be more suitable for climate change. Drought stress is one of the most challenging problems in cotton production in Egypt and worldwide. Drought only affects 45% of the world's agricultural land, additional, 19.5% of irrigated lands are saline. Drought with salinization is ordinary to cause up to 50% of arable land loss worldwide in the next 40 years (Wang, *et al.*, 2003). In Texas during 1998 and 2009 drought caused more than 500 million dollars in cotton losses (Phillips 1998 and Fannin 2006). Improvement of drought heat and/or salt stress tolerant genotypes represents one of the most useful solutions. Genetic variation in abiotic stress tolerance exists within cotton genotypes. In 2015, United States Department of Agriculture (USDA) predicted that a future decline in cotton production might occur in the presence of drought stress. Indeed, cotton industry has been affected by drought and heat stress, leading to a loss of fiber yield by 34% (Ullah, *et al.*, 2017). The total area of cotton in 2018 reached about 32.95 million hectares worldwide with average production 1.37 metric tons/ha. Gave total production 45.15 million metric tons. Whereas, the total area of cotton reached about 33.58 million hectares worldwide with average yield 803 kg/ha. given total production 123.78 (million 480 Ib. bales). In the meantime, in Egypt, the area of cotton during 2018/2019 is 0.14 million hectares with average production 1.08 metric tons/ha. given total production 0.15 million metric tons (USDA, 2022).

Based on results obtained by (El Kadi, *et al.*, 2021), evaluated genotypes obtained from a biparental mating system for drought tolerance. In first season, F_2 seeds from two crosses (G.93 × Menofy) and (G.96× C.B58) were planted to obtain F_2 population. Biparental mating system was applied to obtain 32 genotypes for each cross.

In second season 64 genotypes were evaluated for drought tolerance. Derived of 64 genotypes, 12

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superior genotypes were selected according to drought tolerance indices.

Keeping the importance of production of cotton crop in view, yield and its component, earliness traits and fiber quality were studied to satisfy the following objectives.

(i) Evaluation of 12 superior genotypes characterized by specific traits related to drought tolerance.
(ii) Effectiveness estimation of ten drought tolerance indices for screening and identification of drought tolerant cotton genotypes using principal component and rank correlation.
(iii) Studying the interrelationships among the 12 superior genotypes using cluster analysis.

MATERIALS AND METHODS

In 2018 growing season, A field experiment was conducted at Sakha Research Station –Kafr El Shikh, Egypt in a split plot design with randomized complete blocks (RCB) arrangement in 3 replications. Main plots were assigned to the two irrigation regimes (well-watering and water-stress) and sub plots were assigned to the superior 12 genotypes of the two cotton crosses. Each sub-subplot consisted of one row with 4.0 m. long and 0.70 m. in width and comprised 14 plants spacing 30 cm apart and two plants / hill.

Data were recorded for the Following Traits:

1. Seed cotton yield/ plant in grams (SCY/P): measured as average weight of seed cotton yield picked from 10 guarded plants.
2. Lint cotton yield/ plant in grams (LY/P): measured as average weight of lint cotton yield of 10 guarded plants.
3. Fiber length (FL): measured as 2.5% span length by fibrograph.

Fiber property tests were made according to the American society for testing materials A.S.T.M. (1998).

STATISTICAL PROCEDURES:

Analysis of Variance

The statistical analysis of the data on individual character was carried out on the mean values over three replications. The statistical methods adopted are as follows. Collected data were subjected to the proper of statistical analysis of variance (ANOVA) of split plot design as mentioned by Gomez and Gomez, (1984) using MSTAT-C software package (Freed, *et al*., 1989).

Calculation of Drought Tolerance Indices

The formula for each of ten drought tolerance indices used in this study are presented table 1.

Table 1: Drought tolerance indices were calculated using the following equations

Index name	Outcome	Formula	Reference
Stress Tolerance Index (STI)	The genotypes with high STI values will be tolerant to drought stress	$STI=(Y_P \times Y_S)/(\bar{Y}_P)^2$	(Fernandez, 1992)
Mean Productivity (MP)	The genotypes with high value of this index will be more desirable	$MP = \frac{Y_s + Y_p}{2}$	(Rosielle and Hamblin, 1981)
Geometric Mean Productivity (GMP)	The genotypes with high value of this index will be more desirable	$GMP = \sqrt{(Y_p)(Y_s)}$	(Kristin, *et al*., 1997)
Harmonic Mean (HM)	The genotypes with high value of this index will be more desirable	$HM = \frac{2(Y_p \, x \, Y_s)}{Y_p + Y_s}$	(Jafari, *et al*., 2009)
Tolerance index (TOL)	The genotypes with low values of this index are more stable in two different conditions.	$TOL = Y_P - Y_S$	(Rosielle and Hamblin, 1981)
Stress Susceptibility Index (SSI)	The genotypes with SSI<1 are more resistant to drought stress conditions.	$SSI = \frac{1-(Y_s / Y_p)}{1-(\bar{Y}_s / \bar{Y}_p)}$	(Fisher and Maurer, 1978)
Yield Stability Index (YSI)	The genotypes with high YSI values can be regarded as stable genotypes under stress and non-stress conditions.	$YSI = Y_S / Y_P$	(Bouslama and Schapaugh,1984)
Yield reduction ratio (YR)	The genotypes with low value of this index will be suitable for drought stress condition	$YR = 1- (Y_S/ Y_P)$	(Golestani–Araghi and Assad, 1998)
Drought Resistance Index (DI)	The genotypes with high value of this index will be suitable for drought stress condition	$DI = \frac{Ys(Ys \;/ Yp)}{\bar{Y}p}$	(Lan, 1998)
Yield Index (YI)	The genotypes with high value of this index will be suitable for drought stress condition	$YI = Y_S / \bar{Y}_S$	(Gavuzzi. *et al*., 1997)

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In the above formulae, Yp and Ys are the mean yield of genotypes under well watering and stress conditions, respectively. $\bar{Y}_p$ and $\bar{Y}_s$ are the mean yield of all genotypes under well watering and stress conditions, respectively.

Ranking Method

For screening drought tolerant genotypes a rank sum (RS) was calculated by the following formula Rank sum (RS) = Rank mean ($\bar{R}$) + Standard deviation of rank (SDR) and SDR= $\sqrt{S_i^2}$ (Farshadfar and Elyasi, 2012).

Standard deviation of ranks (SDR) was measured as:

$$S_i^2 = \frac{\sum_{i=1}^{m}(R_{ij} - \bar{R}_{i.})^2}{n-1}$$

Where R_{ij} is the rank of *in vivo* drought tolerance indicator and $R_{i.}$ is the mean rank across all drought tolerance indicators and SDR = $\sqrt{S_i^2}$ for each genotype.

Principal Component, Correlation, and Cluster Analysis

SPSS Ver 17 was used for principle component analysis and Spearman correlation estimates. Also, mini-tab program 13 was used for cluster analysis.

To identify the most desirable drought tolerance indices, spearman correlation coefficients between Ys (yield under stress conditions), Yp (yield under non-stress conditions) and indices of drought tolerance were determined by the cosine of the angle between their vectors (Yan and Rajcan, 2002). In addition, cluster analysis was also performed to assess the level of dissimilarity among the genotypes. A dendrogram was constructed based on squared Euclidean distance.

RESULTS AND DISCUSSION

Breeding for higher yield with good fiber quality is the main objective in cotton improvement programs. The genetic improvement of any crop relies mainly on the presence of substantial magnitude of variability in the population and the extent to which the desirable trait is heritable.

1-ANOVA Analysis

The results of the ANOVA analysis of variance for under water-stressed and non-stressed environments over the growing seasons, (2018) are presented in Table 2.

The results of the split plot analysis of variance for days to first flower, seed cotton yield, lint yield and fiber length under water-stressed and non-stressed environments are presented in (Table 3). The effects due to the irrigation (factor A) were found to be significant (P< 0.05) for all traits under the study which mean that irrigation is effective for these traits. Abdelbary, *et al*., 2021

The genotypes (factor B) were significant for all traits.

AxB interaction exhibited significant differences for all traits under the study the significant of the interaction mean that each genotype differentiates from others in its response to stress.

Table 2: split plot analysis of variance for some earliness traits, Yield and its components and Fiber quality for 12 superior genotypes of two cotton crosses (G.93 × Menofy) and (G.96× C.B58) in 2018 growing season

Source of variance	d.f	DFF	SCY /p	LY/p	fiber length
Reps	2	0.889	1.38	0.106	0.388
factor A (stress)	1	133.389**	12225.268**	1406.002**	54.601**
Error	2	0.389	1.52	0.116	0.203
factor B (genotypes)	11	83.192**	526.859**	65.394**	1.054**
AxB	11	42.722**	64.771**	15.66**	1.099**
Error	44	0.275	1.213	0.374	0.163

**: significance at 0.01 level of probability.

DFF, SCY, LY: days to first flower, seed cotton yield and lint yield respectively.

2. Screening Drought Tolerant Genotypes and Indices

a. Comparing Genotypes Based On Tolerance Indices

2. A.1 - Yield and its Component

- **Seed Cotton Yield and Lint Yield**

To investigate suitable stress resistance indices for screening of genotypes under drought condition, yield of genotypes under both non-stress and stress conditions were measured for calculating different sensitivity and tolerance indices (Table 5). A suitable index must have a significant correlation with yield under both the conditions (Mitra, 2001).

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The parameters of stress tolerance index (STI) and geometric mean productivity (GMP) were calculated as proposed by Fernandez, (1992). Beside, mean productivity (MP) proposed by Rosielle and Hamblin, (1981) as mean production under both water stressed and non-stressed conditions were employed to more description of the response of the genotypes. The genotypes with high values of these parameters can be selected as tolerant genotypes to water stress. According to STI, MP and GMP values, genotypes G4 and G5 identified as drought tolerant genotypes for seed cotton yield (table 4) and lint cotton yield (table 5). These genotypes had greater values for STI, MP and GMP. While the genotype G6 identified as susceptible genotype for seed cotton yield (table 3) and lint cotton yield (table 3), because of his low value for STI, MP and GMP.

Table 3: Estimates of different drought tolerance indices for 12 superior genotypes of two cotton crosses (G.93 × Menofy) and (G.96× C.B58) based on seed cotton yield / plant under normal (Yp) and drought (Ys) conditions in 2018 growing season

	Y P	**Y S**	**STI**	**MP**	**GMP**	**HM**	**TOI**	**SSI**	**YSI**	**YR**	**DI**	**YI**
G1	84.77	50.1	0.59	67.44	65.17	62.98	34.67	1.33	0.59	0.41	0.50	0.59
G2	82.77	49	0.56	65.87	63.67	61.53	33.80	1.33	0.59	0.41	0.49	0.58
G3	85.63	63.4	0.75	74.50	73.66	72.84	22.26	0.85	0.74	0.26	0.80	0.75
G4	97.1	71.3	0.96	84.20	83.21	82.22	25.80	0.87	0.73	0.27	0.89	0.84
G5	95.5	77.6	1.03	86.57	86.10	85.64	17.87	0.61	0.81	0.19	1.07	0.91
G6	74.73	36.7	0.38	55.73	52.39	49.25	38.00	1.66	0.49	0.51	0.31	0.43
G7	92.27	69.2	0.88	80.72	79.89	79.07	23.10	0.82	0.75	0.25	0.88	0.81
G8	75.27	50.1	0.52	62.69	61.41	60.16	25.17	1.09	0.67	0.33	0.57	0.59
G9	87.33	62.3	0.75	74.82	73.76	72.72	25.03	0.94	0.71	0.29	0.75	0.73
G10	75.4	52.7	0.55	64.04	63.02	62.02	22.73	0.98	0.70	0.30	0.62	0.62
G11	86.17	69.7	0.83	77.94	77.50	77.06	16.47	0.62	0.81	0.19	0.96	0.82
G12	83.43	55.6	0.64	69.52	68.11	66.73	27.83	1.09	0.67	0.33	0.63	0.65

$\mathbf{Y_P}$ = seed cotton yield under non-stress condition, $\mathbf{Y_S}$ = seed cotton yield under water stress condition, **STI** = Stress tolerance index, **TOL** = Tolerance index, **MP** = Mean productivity, **GMP** = Geometric mean productivity, **SSI** = Stress susceptibility index, **YI** = Yield index, **YSI =** Yield stability index, **YR** = Yield reduction ratio, **HM** = Harmonic mean and **DI** = Drought resistance index.

Tolerance index (TOL) as defined by Rosielle and Hamblin, (1981) as the difference in yield between grain yield/plant under both water stressed and non-stressed conditions was used to select tolerant genotypes to water stress, where the genotypes with low TOL value would be more tolerant to water stress the selection must be done based on low rates of TOL (Mohammadi, *et al*., 2011). At the same time, stress susceptibility index (SSI) proposed by Fischer and Maurer, (1978) estimates the rate of change for each genotype in yield between the stress and non-stress conditions relative to the mean change for all genotypes. Values of SSI lower than 1 denotes low drought susceptibility (or high yield stability) and values higher than 1 indicate high drought susceptibility (or poor yield stability). Clarke, *et al.*, (1982) used stress susceptibility index (SSI) for evaluation of drought tolerance in wheat genotypes and found year-to-year variation in SSI for genotypes and their ranking pattern. Guttieri, *et al.*, (2001) used SSI criterion and suggested that SSI more than 1 indicated above-average susceptibility to drought stress.

Also, yield reduction ratio (YR) (Golestani–Araghi and Assad, 1998) with low value would be more tolerant to water stress. Genotype G5 with low SSI and TOL for seed cotton yield (table 3) and lint cotton yield (table 4) were identified as drought resistant genotypes and desirable for stress condition. It seems that indices TOL and SSI had succeeded in selection of genotypes with high yield under drought stress, but had failed to select genotypes with proper yield under both environments.

Yield index (YI) was computed as suggested by Gavuzzi, *et al.*, (1997). The high values of YI index characterize tolerant genotypes. So, genotypes G4 and G5 identified as drought tolerant genotypes for seed cotton yield (table 4) and lint cotton yield (table 5) Finally, yield stability index (YSI) (Bouslama and Schapaugh, 1984), drought resistance index (DI) (Lan, 1998) and harmonic mean (HM) (Kristin, *et al*., 1997) were also used in Tables 4 and 5. The genotypes with high values of these parameters can be selected as tolerant genotypes to water stress. In this study, genotype

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G5 identified as drought tolerant genotypes for both traits for seed cotton yield (table 3) and lint cotton yield (table 4). This genotype G5 identified as drought tolerant genotype for YSI.

Table 4: Estimates of different drought tolerance indices for 12 superior genotypes of two cotton crosses (G.93 × Menofy) and (G.96× C.B58) based on lint cotton yield / plant under normal (Yp) and drought (Ys) conditions in 2018 growing season

	Y P	**Y S**	**STI**	**MP**	**GMP**	**HM**	**TOI**	**SSI**	**YSI**	**YR**	**DI**	**YI**
G1	30.02	18	0.57	23.99	23.22	22.47	12.06	1.40	0.60	0.40	0.49	0.58
G2	30.68	18	0.58	24.32	23.47	22.65	12.73	1.45	0.59	0.41	0.48	0.58
G3	30.34	25.5	0.81	27.90	27.79	27.69	4.88	0.56	0.84	0.16	0.97	0.83
G4	36.09	27.1	1.03	31.60	31.27	30.96	8.99	0.87	0.75	0.25	0.92	0.88
G5	33.23	27.3	0.95	30.26	30.11	29.96	5.95	0.62	0.82	0.18	1.02	0.88
G6	27.86	13.2	0.39	20.51	19.15	17.88	14.70	1.84	0.47	0.53	0.28	0.43
G7	32.61	26.5	0.91	29.54	29.38	29.22	6.14	0.66	0.81	0.19	0.98	0.86
G8	27.06	19.2	0.55	23.13	22.79	22.46	7.86	1.01	0.71	0.29	0.62	0.62
G9	31.89	23.2	0.78	27.55	27.21	26.87	8.68	0.95	0.73	0.27	0.77	0.75
G10	29.15	19.8	0.61	24.46	24.01	23.56	9.38	1.12	0.68	0.32	0.61	0.64
G11	30.63	26.3	0.85	28.46	28.37	28.29	4.35	0.50	0.86	0.14	1.02	0.85
G12	30.51	20.2	0.65	25.34	24.80	24.28	10.35	1.18	0.66	0.34	0.61	0.65

$\mathbf{Y_P}$ = lint cotton yield under non-stress condition, $\mathbf{Y_S}$ = lint cotton yield under water stress condition, **STI** = Stress tolerance index, **TOL** = Tolerance index, **MP** = Mean productivity, **GMP** = Geometric mean productivity, **SSI** = Stress susceptibility index, **YI** = Yield index, **YSI =** Yield stability index, **YR** = Yield reduction ratio, **HM** = Harmonic mean and **DI** = Drought resistance index.

2. b.2 - Fiber Quality

- **Fiber Length**

The genotypes with high values of these parameters can be selected as tolerant genotypes to water stress. According to STI, MP and GMP values, genotypes G_6, G_1, G_8, and G_{10} identified as drought tolerant genotypes. These genotypes had greater values for STI, MP and GMP. While the genotypes G_2, G_3, and G_{12} identified as susceptible genotypes, because of their low values for STI, MP and GMP.

The genotypes with low TOL value would be more tolerant to water stress. At the same time, stress susceptibility index (SSI) estimates the rate of change for each genotype in yield between the stress and non-stress conditions relative to the mean change for all genotypes. Values of SSI lower than 1 denotes low drought susceptibility and values higher than 1 indicate high drought susceptibility.

Also, yield reduction ratio (YR) with low value would be more tolerant to water stress. Calculation of TOL, SSI and YR showed that the highest stress tolerance (TOL) value and stress susceptibility index (SSI) value were related to G_1, and G_7 indicating that these genotypes had fiber length reduction under stress conditions and the highest drought sensitivity. Genotypes G_3, G_8, and G_{12} with low SSI and TOL (Table 5) were identified as drought resistant genotypes and desirable for stress condition.

The high values of YI index characterize tolerant genotypes. So, genotypes G_6, G_8 and G_{10} identified as drought tolerant genotypes. Finally, yield stability index (YSI) drought resistance index (DI) and harmonic mean (HM) were also used in Table 5. The genotypes with high values of these parameters can be selected as tolerant genotypes to water stress. In this study, genotypes G_3, and G_8 identified as drought tolerant genotypes. These genotypes had greater values for DI and HM. However, G1, and G7 identified as drought tolerant genotypes for YSI. Chen, *et al*., (2015) and Chu, *et al*., (2015).

Table 5: Estimates of different drought tolerance indices for 12 superior genotypes of two cotton crosses (G.93 × Menofy) and (G.96× C.B58) based on fiber length under normal (Yp) and drought (Ys) conditions in 2018 growing season

	Y P	**Y S**	**STI**	**MP**	**GMP**	**HM**	**TOI**	**SSI**	**YSI**	**YR**	**DI**	**YI**
G1	36.73	33.6	0.97	35.17	35.13	35.10	3.13	1.74	0.91	0.09	0.91	0.94
G2	35.47	33.3	0.93	34.39	34.37	34.35	2.17	1.25	0.94	0.06	0.92	0.93
G3	34.5	34.1	0.93	34.32	34.31	34.31	0.37	0.22	0.99	0.01	1.00	0.96

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G4	35.9	33.8	0.95	34.85	34.83	34.82	2.10	1.19	0.94	0.06	0.94	0.95
G5	35.5	33.5	0.94	34.50	34.49	34.47	2.00	1.15	0.94	0.06	0.93	0.94
G6	35.87	34.6	0.98	35.22	35.21	35.21	1.30	0.74	0.96	0.04	0.98	0.97
G7	36.67	33.3	0.96	35.00	34.96	34.92	3.34	1.86	0.91	0.09	0.89	0.93
G8	35.73	34.6	0.97	35.18	35.18	35.17	1.10	0.63	0.97	0.03	0.99	0.97
G9	35.53	34.1	0.95	34.80	34.79	34.78	1.46	0.84	0.96	0.04	0.96	0.96
G10	35.73	34.5	0.97	35.10	35.09	35.09	1.26	0.72	0.96	0.04	0.98	0.97
G11	35.77	34.2	0.96	35.00	34.99	34.98	1.54	0.88	0.96	0.04	0.97	0.96
G12	34.47	33.3	0.90	33.90	33.90	33.89	1.14	0.68	0.97	0.03	0.95	0.93

Y_P = fiber length under non-stress condition, **Y_S** = fiber length under water stress condition, **STI** = Stress tolerance index, **TOL** = Tolerance index, **MP** = Mean productivity, **GMP** = Geometric mean productivity, **SSI** = Stress susceptibility index, **YI** = Yield index, **YSI =** Yield stability index, **YR** = Yield reduction ratio, **HM** = Harmonic mean and **DI** = Drought resistance index.

3. Correlation Analysis

3. A.1 - Yield and its Component

- **Seed Cotton Yield and Lint Yield**

To determine the most desirable drought tolerant criteria, the correlation coefficients between Yp, Ys, and other quantitative indices of drought tolerance were calculated. In other words, correlation analysis between seed and lint cotton yield and drought tolerance indices can be a good criterion for screening the best genotypes and indices used Table (6) and table (7). A suitable index must have a significant correlation with seed and lint cotton yield under both the conditions (Mitra, 2001).

Spearman's rank correlation coefficients between the drought tolerance indices and mean seed cotton yield under stress and non-stress conditions are given in Table (6) and Spearman's rank correlation coefficients between the drought tolerance indices and mean lint cotton yield under stress and non-stress conditions are given in Table (7). Seed cotton yield under water stress conditions had positive and highly significant correlation with seed cotton yield under non-stress conditions (r = 0.90**). Lint cotton yield under water stress conditions had positive and high significant correlation with lint cotton yield under non-stress conditions (r = 0.771**).These results indicated that high seed cotton yield and lint cotton yield performance under optimal conditions necessarily result in improved yield under stress conditions.

Table 6: Spearman's rank correlation coefficients between seed cotton yield and drought tolerance indices 12 superior genotypes of cotton crosses (G.93 × Menofy) and (G.96× C.B58) in 2018 growing seasond

	Yp	Ys	STI	MP	GMP	HM	TOI	SSI	YSI	YR	DI
Ys	.90**										
STI	.97**	.95**									
MP	.98**	.94**	.998**								
GMP	.98**	.94**	.998**	.998**							
HM	.96**	.97**	.99**	.986**	.99**						
TOI	-.47	-.74**	-.57	-.56	-.56	-.62*					
SSI	-.78**	-.94**	-.85**	-.85**	-.85**	-.88**	.90**				
YSI	.77**	.93**	.85**	.84**	.84**	.88**	-.91**	-.998**			
YR	-.77**	-.93**	-.85**	-.84**	-.84**	-.88**	.91**	.998**	-1.00**		
DI	.85**	.99**	.92**	.92**	.92**	.94**	-.80**	-.97**	.96**	-.96**	
YI	.90**	0.998**	.95**	.94**	.94**	.97**	-.74**	-.94**	.93**	-.93**	.99**

* and ** indicate significance at 0.05 and 0.01 probability , respectively**.** **Y_P** = seed cotton yield under non-stress condition, **Y_S** = seed cotton yield under water stress condition, **STI** = Stress tolerance index, **TOL** = Tolerance index, **MP** = Mean productivity, **GMP** = Geometric mean productivity, **SSI** = Stress susceptibility index, **YI** = Yield index, **YSI =** Yield stability index, **YR** = Yield reduction ratio, **HM** = Harmonic mean and **DI** = Drought resistance index.

Significant positive correlation was found between both seed and lint cotton yield in the stress (Ys) and non-stress (Yp) conditions with stress tolerance index (STI), mean productivity (MP), geometric mean productivity (GMP), harmonic mean (HM), Yield stability index (YSI), drought resistance index (DI), and yield index (YI),

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indicating that these criteria discriminated drought tolerant genotypes with high seed cotton yield under stress and non-stress environments.

Table 7: Spearman's rank correlation coefficients between lint cotton yield and drought tolerance indices 12 superior genotypes of cotton crosses (G.93 × Menofy) and (G.96× C.B58) in 2018 growing season

	Yp	Ys	STI	MP	GMP	HM	TOI	SSI	YSI	YR	DI
Ys	.771**										
STI	.860**	.970**									
MP	.860**	.970**	.990**								
GMP	.860**	.970**	.998**	.990**							
HM	.860**	.970**	.997**	.997**	.990**						
TOI	-.308	-.760**	-.650*	-.650*	-.650*	-.650*					
SSI	-.462	-.858**	-.790**	-.790**	-.790**	-.790**	.972**				
YSI	.462	.858**	.790**	.790**	.790**	.790**	-.972**	-0.98			
YR	-.462	-.858**	-.790**	-.790**	-.790**	-.790**	.972**	.999**	-0.992		
DI	.565	.917**	.839**	.839**	.839**	.839**	-.944**	-.972**	.972**	-.972**	
YI	.775**	.998**	.975**	.975**	.975**	.975**	-.747**	-.853**	.853**	-.853**	.907**

* and ** indicate significance at 0.05 and 0.01 probability , respectively**.** $\mathbf{Y_P}$ = lint cotton yield under non-stress condition, $\mathbf{Y_S}$ = lint cotton yield under water stress condition, **STI** = Stress tolerance index, **TOL** = Tolerance index, **MP** = Mean productivity, **GMP** = Geometric mean productivity, **SSI** = Stress susceptibility index, **YI** = Yield index, **YSI =** Yield stability index, **YR** = Yield reduction ratio, **HM** = Harmonic mean and **DI** = Drought resistance index.

The results of this experiment demonstrated that the most appropriate index to select drought tolerant genotype is an index which has a high correlation with yield under both non-stress and stress conditions. So, STI, MP, GMP, HM, YSI, DI and YI were identified as appropriate indices to select drought tolerance genotypes. Farooq, *et al*., (2016) showed that correlation between MP, GMP, Ys and Yp was positive. Shakeel, *et al*., (2018) reported that GMP, MP and STI were significantly and positively correlated with stress yield. Likewise, Khalili, *et al*., (2012) reported that GMP, MP, and STI were significantly and positively correlated with stress yield. Jarwar, *et al.*, (2019) found that STI and GMP were more suitable indices to select genotypes that perform well in both stress and non-stress conditions. Similar results were reported Farooq, *et al.*, (2013).

Negative correlations were observed inYSI in stress (Ys) and non-stress (Yp) conditions for both seed cotton yield and lint cotton yield. Maji, *et al*., (2011) reported positive and significant correlations between Yp with TOL, MP, GMP, STI, SSI and HM selection indices. reported that correlations between YS with GMP, STI, and HM showed that selection based on these indices may increase yield in stress and non-stress conditions.

3. B.2 - Fiber Quality

- **Fiber Length**

To determine the most desirable drought tolerant criteria, the correlation coefficients between Yp, Ys, and other quantitative indices of drought tolerance were calculated. In other words, correlation analysis between grain yield and drought tolerance indices can be a good criterion for screening the best genotypes and indices used (Table 8). A suitable index must have a significant correlation with fiber length under both the conditions.

Spearman's rank correlation coefficients between the drought tolerance indices and mean fiber length under stress and non-stress conditions are given in Table 8. Fiber length under water stress conditions had positive and highly significant correlation with fiber length under non-stress conditions (r = 0.789**). This result indicated that high fiber length performance under optimal conditions necessarily result in improved fiber length under stress conditions.

Significant positive correlation was found between fiber length in the stress (Ys) and non-stress (Yp) conditions with stress tolerance index (STI), mean productivity (MP), geometric mean productivity (GMP), and harmonic mean (HM) indicating that these criteria discriminated drought tolerant genotypes with high grain yield under stress and non-stress environments (group A: genotypes that express uniform superiority in both environmental conditions) (Fernandez, 1992) (Table 8). Same results were obtained by Yehia amd El-Hashash, (2021).

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The results of this experiment demonstrated that the most appropriate index to select drought tolerant genotype is an index which has a high correlation with grain yield under both non-stress and stress conditions. So, STI, MP, GMP, and HM were identified as appropriate indices to select drought tolerance genotypes.

By looking at the correlations between indices, no significant correlation was observed between (Ys) with tolerance index (TOL), stress susceptibility index (SSI), Yield stability index (YSI), and yield reduction ratio (YR), hence these indicators were not able to identify drought tolerant genotypes (group C). Significant correlations were not observed between SSI, YSI and YR with fiber length in stress (Ys) and non-stress (Yp) conditions.

Also, the correlation among STI, MP, GMP, and HM were positive and highly significant.

Table 8: Spearman's rank correlation coefficients between fiber length and drought tolerance indices 12 superior genotypes of cotton crosses (G.93 × Menofy) and (G.96× C.B58) in 2018 growing season

	Yp	**Ys**	**STI**	**MP**	**GMP**	**HM**	**TOI**	**SSI**	**YSI**	**YR**	**DI**
Ys	.789**										
STI	.748**	.676*									
MP	.761**	.655*	.989**								
GMP	.750**	.678*	.988**	.998**							
HM	.750**	.678*	.988**	.998**	.990**						
TOI	.588*	-.565	.074	.102	.084	.084					
SSI	.588*	-.565	.074	.102	.084	.084	.998**				
YSI	-.634*	.496	-.180	-.198	-.176	-.176	-.972**	-.972**			
YR	.634*	-.496	.180	.198	.176	.176	.972**	.972**	.990**		
DI	-.346	.809**	.177	.147	.172	.172	-.914**	-.914**	.887**	-.887**	
YI	.122	.987**	.630*	.595*	.616*	.616*	-.605*	-.605*	.518	-.518	.832**

* and ** indicate significance at 0.05 and 0.01 probability , respectively. **Y_P** = fiber length under non-stress condition, **Y_S** = fiber length under water stress condition, **STI** = Stress tolerance index, **TOL** = Tolerance index, **MP** = Mean productivity, **GMP** = Geometric mean productivity, **SSI** = Stress susceptibility index, **YI** = Yield index, **YSI** = Yield stability index, **YR** = Yield reduction ratio, **HM** = Harmonic mean and **DI** = Drought resistance index.

4. RANKING METHOD

4. A.1 - Yield and its Component

- **Seed Cotton Yield and Lint Yield**

Table 9: Rank, rank mean ($\bar{R}$), standard deviation of ranks (SDR) and rank sum (RS) of drought tolerance indices for indices for 12 superior genotypes of two cotton crosses (G.93 × Menofy) and (G.96× C.B58) based on seed cotton yield under well watering (Yp) and stress (Ys) conditions

Genotypes	**Y P**	**Y S**	**STI**	**MP**	**GMP**	**HM**	**TOI**	**SSI**	**YSI**	**YR**	**DI**	**YI**	**$\bar{R}$**	**SDR**	**RS**
G1	7	9	8	8	8	8	2	2	11	2	10	9	7.00	3.19	10.19
G2	9	11	9	9	9	10	3	3	10	3	11	11	8.17	3.21	11.38
G3	6	5	6	6	6	5	10	9	4	9	5	5	6.33	1.92	8.26

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G4	1	2	2	2	2	2	5	8	5	8	3	2	3.50	2.43	5.93
G5	2	1	1	1	1	1	11	12	1	12	1	1	3.75	4.79	8.54
G6	12	12	12	12	12	12	1	1	12	1	12	12	9.25	4.97	14.22
G7	3	4	3	3	3	3	8	10	3	10	4	4	4.83	2.79	7.62
G8	11	10	11	11	11	11	6	4	9	4	9	10	8.92	2.71	11.63
G9	4	6	5	5	5	6	7	7	6	7	6	6	5.83	0.94	6.77
G10	10	8	10	10	10	9	9	6	7	6	8	8	8.42	1.51	9.92
G11	5	3	4	4	4	4	12	11	2	11	2	3	5.42	3.68	9.10
G12	8	7	7	7	7	7	4	5	8	5	7	7	6.58	1.24	7.82

$\mathbf{Y_P}$ = seed cotton yield under non-stress condition, $\mathbf{Y_S}$ = seed cotton yield under water stress condition, **STI** = Stress tolerance index, **TOL** = Tolerance index, **MP** = Mean productivity, **GMP** = Geometric mean productivity, **SSI** = Stress susceptibility index, **YI** = Yield index, **YSI =** Yield stability index, **YR** = Yield reduction ratio, **HM** = Harmonic mean and **DI** = Drought resistance index

The estimates of indicators of drought tolerance indicated that the identification of drought-tolerant varieties was contradictory based on a single criterion. Different indices introduced different genotypes as drought tolerant. The following ranking method was used to have an overall judgment. To determine the most desirable drought tolerant genotype according to the all indices, mean rank, standard deviation of ranks and rank sum (RS) of all drought tolerance criteria were calculated and based on these three criteria the most desirable drought tolerant genotypes were identified in Table (7) for seed cotton yield. In consideration to all indices, genotype G4, exhibited the best mean rank and almost low standard deviation of rank, with least RS was the most drought tolerant followed by genotype G9, while genotype G6 was identified as the most drought sensitive genotypes (Table (7)). For lint cotton yield (table 8) genotype G4, exhibited the best mean rank and almost low standard deviation of rank, with least RS was the most drought tolerant followed by genotype G9, while genotype G6 was identified as the most drought sensitive genotypes. Therefore, they are recommended to be used as parents for genetic analysis and improvement of drought tolerance in cotton. Ranking method has been used for screening drought tolerant varieties by Yehia, (2021) in cotton.

Table 10: Rank, rank mean ($\bar{R}$), standard deviation of ranks (SDR) and rank sum (RS) of drought tolerance indices for indices for 12 superior genotypes of two cotton crosses (G.93 × Menofy) and (G.96× C.B58) based on lint cotton yield under well watering (Yp) and stress (Ys) conditions

	Y P	**Y S**	**(STI)**	**(MP)**	**(GMP)**	**(HM)**	**(TOI)**	**(SSI)**	**(YSI)**	**(YR)**	**(DI)**	**(YI)**	**$\bar{R}$**	**SDR**	**RS**
G1	9	10	10	10	10	10	3	3	10	3	10	10	8.17	3.13	11.30
G2	5	11	9	9	9	9	2	2	11	2	11	11	7.58	3.75	11.34
G3	8	5	5	5	5	5	11	11	2	11	4	5	6.42	3.06	9.48
G4	1	2	1	1	1	1	6	8	5	8	5	2	3.42	2.81	6.23
G5	2	1	2	2	2	2	10	10	3	10	2	1	3.92	3.70	7.62
G6	11	12	12	12	12	12	1	1	12	1	12	12	9.17	4.93	14.10
G7	3	3	3	3	3	3	9	9	4	9	3	3	4.58	2.68	7.26
G8	12	9	11	11	11	11	8	6	7	6	7	9	9.00	2.17	11.17
G9	4	6	6	6	6	6	7	7	6	7	6	6	6.08	0.79	6.88
G10	10	8	8	8	8	8	5	5	8	5	8	8	7.42	1.56	8.98
G11	6	4	4	4	4	4	12	12	1	12	1	4	5.67	4.05	9.72
G12	7	7	7	7	7	7	4	4	9	4	9	7	6.58	1.73	8.31

$\mathbf{Y_P}$ = lint cotton yield under non-stress condition, $\mathbf{Y_S}$ = lint cotton yield under water stress condition, **STI** = Stress tolerance index, **TOL** = Tolerance index, **MP** = Mean productivity, **GMP** = Geometric mean productivity, **SSI** = Stress susceptibility index, **YI** = Yield index, **YSI =** Yield stability index, **YR** = Yield reduction ratio, **HM** = Harmonic mean and **DI** = Drought resistance index.

4. B.1 – Fiber Quality

- **Fiber Length**

The estimates of indicators of drought tolerance (Table 4) indicated that the identification of

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drought-tolerant cultivars was contradictory based on a single criterion. Different indices introduced different genotypes as drought tolerant. The following ranking method was used to have an overall judgment. To determine the most desirable drought tolerant genotype according to the all indices, mean rank, standard deviation of ranks and rank sum (RS) of all drought tolerance criteria were calculated and based on these three criteria the most desirable drought tolerant genotypes were identified (Table 6). In consideration to all indices, genotype (G_{11}), exhibited the best mean rank and almost low standard deviation of rank, with least RS was the most drought tolerant followed by genotypes (G_6, G_{10} and G_9), while genotype G_3 was identified as the most drought sensitive (Table 6) Tao, *et al*., (2018) and Zafer, *et al*., (2022).

Table 11: Rank, rank mean ($\bar{R}$), standard deviation of ranks (SDR) and rank sum (RS) of drought tolerance indices for indices for 12 superior genotypes of two cotton crosses (G.93 × Menofy) and (G.96× C.B58) based on fiber length under well watering (Yp) and stress (Ys) conditions

	Y P	Y S	(STI)	(MP)	(GMP)	(HM)	(TOI)	(SSI)	(YSI)	(YR)	(DI)	(YI)	$\bar{R}$	SDR	RS
G1	1	8	3	3	3	3	2	2	11	2	11	8	4.75	3.67	8.42
G2	10	12	10	10	10	10	3	3	10	3	10	12	8.58	3.45	12.03
G3	11	5	11	11	11	11	12	12	1	12	1	5	8.58	4.32	12.90
G4	3	7	7	7	7	7	4	4	9	4	8	7	6.17	1.90	8.07
G5	9	9	9	9	9	9	5	5	8	5	9	9	7.92	1.78	9.70
G6	4	2	1	1	1	1	8	8	5	8	3	2	3.67	2.90	6.57
G7	2	10	6	5	6	6	1	1	12	1	12	10	6.00	4.22	10.22
G8	6	1	2	2	2	2	11	11	2	11	2	1	4.42	4.17	8.58
G9	8	6	8	8	8	8	7	7	6	7	6	6	7.08	0.90	7.98
G10	7	3	4	4	4	4	9	9	4	9	4	3	5.33	2.42	7.76
G11	5	4	5	6	5	5	6	6	7	6	5	4	5.33	0.89	6.22
G12	12	11	12	12	12	12	10	10	3	10	7	11	10.17	2.69	12.86

$\mathbf{Y_P}$ fiber length under non-stress condition, $\mathbf{Y_S}$ = fiber length under water stress condition, **STI** = Stress tolerance index, **TOL** = Tolerance index, **MP** = Mean productivity, **GMP** = Geometric mean productivity, **SSI** = Stress susceptibility index, **YI** = Yield index, **YSI =** Yield stability index, **YR** = Yield reduction ratio, **HM** = Harmonic mean and **DI** = Drought resistance index.

5. Cluster Analysis

5. A.1 - Yield and its Component

- **Seed Cotton Yield and Lint Yield**

The cluster analysis based on squared Euclidean distance was performed to classify the genotypes on the basis of drought tolerance indices. Using cluster analysis with Unweighted Pair Group Method using Arithmetic means (UPGMA) and based on drought tolerance criteria, the result of cluster analysis for studied genotypes has been presented in Fig. 1. Cluster analysis based on drought tolerance indices and seed cotton yield under well watering and stress conditions and Fig. 2. Cluster analysis based on drought tolerance indices and lint cotton yield under well watering and stress conditions classified the genotypes into three groups (Fig. 1 and 2) respectively.

Cluster analysis showed that the genotypes, based on indices tended to group into three groups: tolerant, semi-tolerant and sensitive genotypes (Fig. 1 and 2) respectively. The 12 cotton genotypes based on seed cotton yield and lint cotton yield, and indices were classified in three clusters, each cluster contained genotypes that were highly similar. The first cluster consists of genotypes (G3, G4 and G9). These genotypes had high STI, MP, GMP, YI and YSI values, thus they considered to be the most desirable genotypes for both growth conditions (tolerant group). The second cluster comprising genotypes, these genotypes had mean indicators values therefore, they identified as semi-tolerance or semi-sensitive genotypes. Genotype G6 classified in the third cluster.

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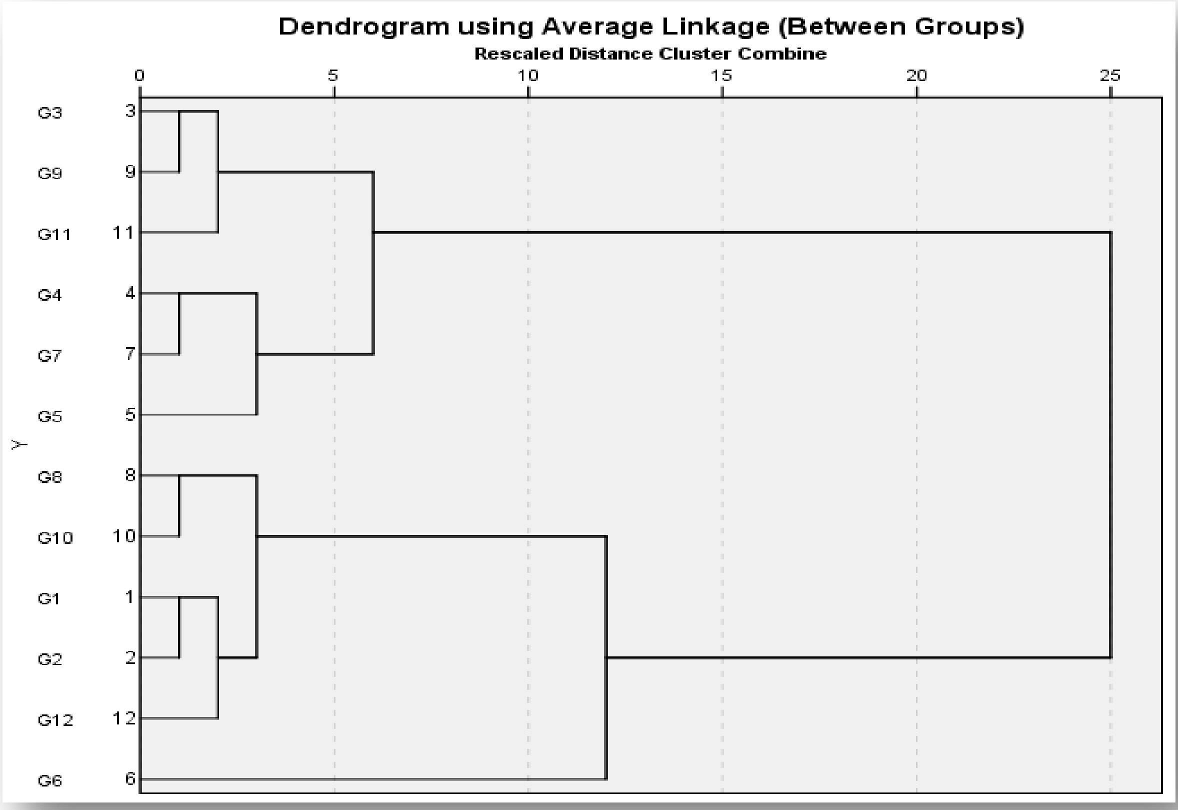

Figure 1: Dendrogram using Ward method between groups showing classification of genotypes based on tolerance indices for seed cotton yield

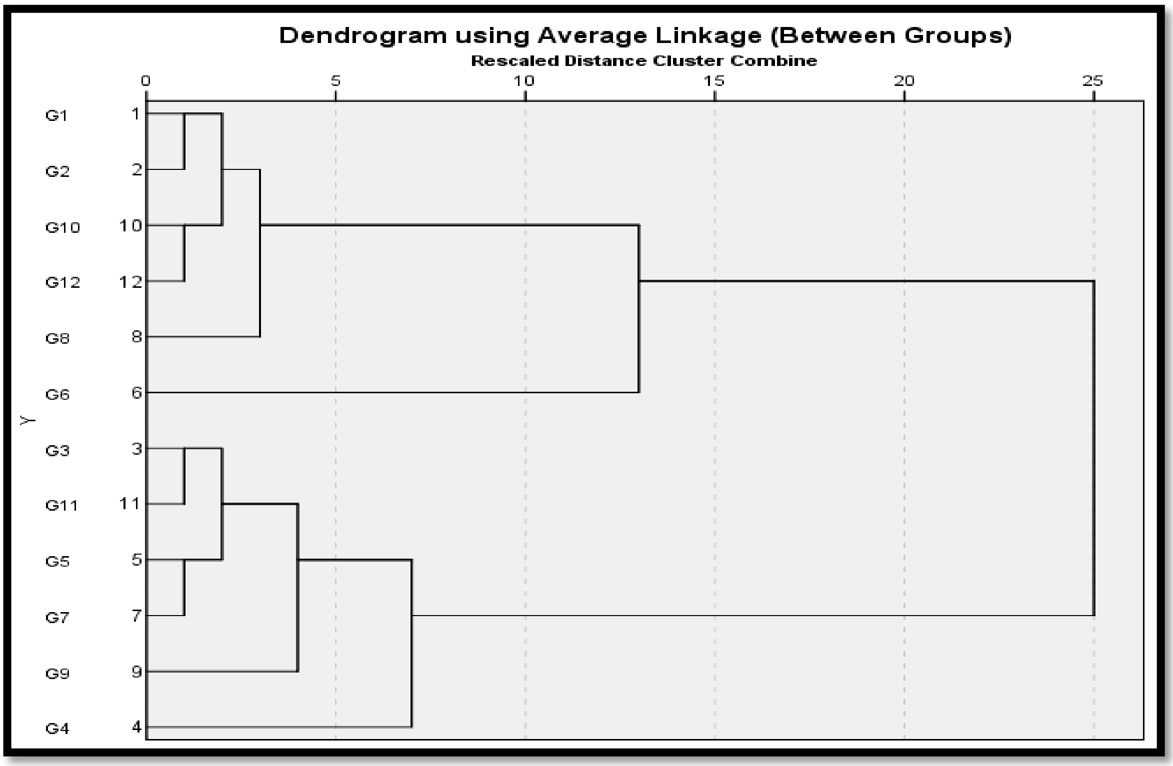

Figure 2: Dendrogram using Ward method between groups showing classification of genotypes based on tolerance indices for lint cotton yield.

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5. B.1 – Fiber Quality

- **Fiber Length**

The cluster analysis based on squared Euclidean distance was performed to classify the genotypes on the basis of drought tolerance indices. Using cluster analysis with Unweighted Pair Group Method using Arithmetic means (UPGMA) and based on drought tolerance criteria, the result of cluster analysis for studied genotypes has been presented in Fig. 3. Cluster analysis based on drought tolerance indices and fiber length under well watering and stress conditions classified the genotypes into three groups (Fig. 1).
Abd El-Mohsen, *et al*., (2014)

Cluster analysis showed that the genotypes, based on indices tended to group into three groups: tolerant, semi-tolerant and sensitive genotypes (Fig. 1). The 12 cotton genotypes based on fiber length and indices were classified in three clusters, each cluster contained genotypes that were highly similar. The first cluster consists of genotypes (G6, G8 and G10). These genotypes had high STI, MP, GMP, YI and YSI values, thus they considered to be the most desirable genotypes for both growth conditions (tolerant group). The second cluster comprising genotypes, these genotypes had mean indicators values therefore, they identified as semi-tolerance or semi-sensitive genotypes. Genotypes (G3 and G12) classified in the third cluster.

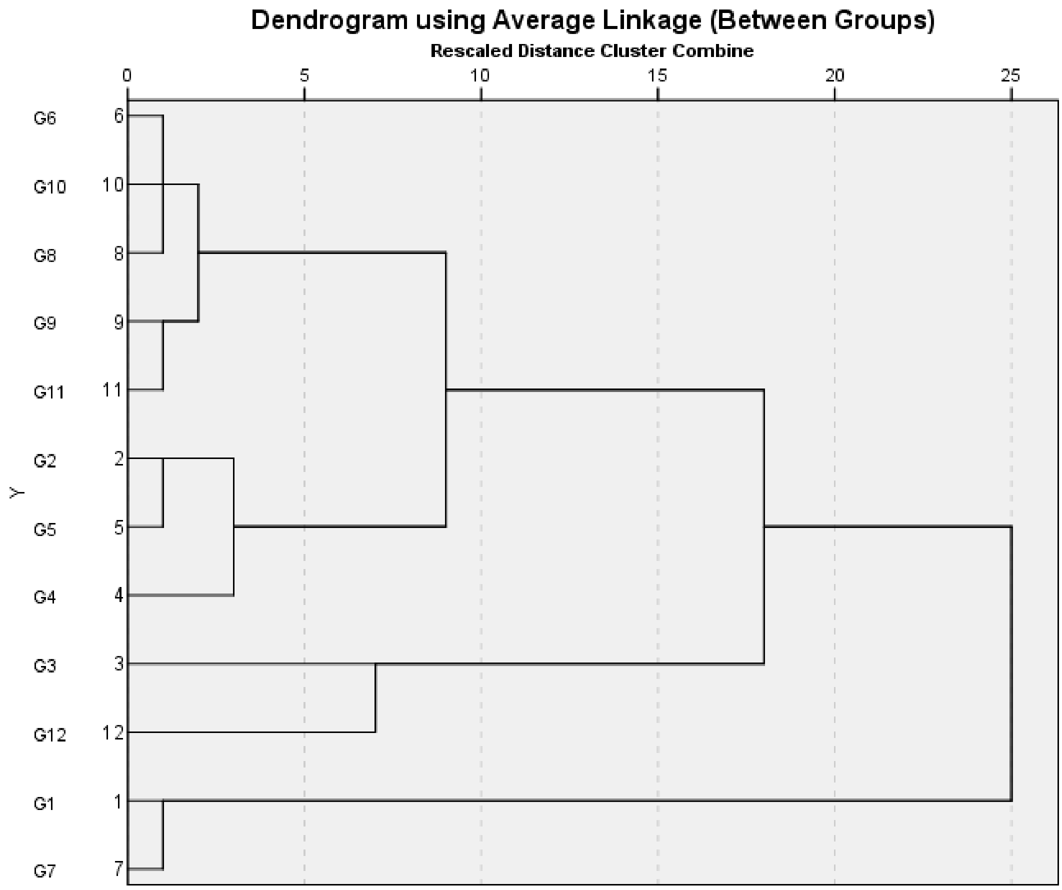

Figure 3: Dendrogram using Ward method between groups showing classification of genotypes based on tolerance indices for fiber length trait in 2018 growing season.

6. Principal Component Analysis.

6. A.1 - Yield and its Component

- **Seed Cotton Yield and Lint Yield**

Plant breeders are employing PCA as a "pattern finding method" to complement cluster analysis (Sajjad, *et al.,* (2011)). The main advantage of using PCA over cluster analysis is that each statistics can be assigned to one group only (Saeed, *et al.*, 2014). The purpose of principal components analysis is to obtain a small number of linear combinations of the 12 variables which account for most of the variability in the data. In this case, 2 components have been extracted, since 2 components had eigenvalues greater than or equal to 1.0 Table (09) and table (10).

The results of the principle component analysis (PCA) showed that the first two components explained 91.041 and 8.779% of the total variation Table (09) for seed cotton yield and for lint yield table (10) showed that the principle component analysis (PCA) showed that the first two

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components explained 89.624 and 10.234% of the total variation. In fact, by the method, twelve indices were reduced to two independent components. Eigen vectors in every component refer to the coefficients or the correlation between the component and the indices. In each component, a high correlation between the component and an index indicating that the index is associated with the direction of the maximum amount of variability in the data set. Same data were recorded by Xie, *et al*., (2020).

Table 12: Principal components analysis of drought tolerance indices for seed cotton yield of 12 superior genotypes of two cotton crosses (G.93 × Menofy) and (G.96× C.B58) in 2018 growing season

Drought tolerance indices	**Component**	
	1	2
Yp	.837	.546
Ys	.998	.055
STI	.972	.228
MP	.967	.254
GMP	.979	.203
HM	.986	.161
TOI	-.852	.522
SSI	-.953	.299
YSI	.948	-.316
YR	-.948	.316
DI	.994	-.065
YI	.998	.054
Eigen value	10.925	1.054
Percent of variance	91.041	8.779
Cumulative percentage	91.041	99.82

Y_P = seed cotton yield under non-stress condition, **Y_S** = seed cotton yield under water stress condition, **STI** = Stress tolerance index, **TOL** = Tolerance index, **MP** = Mean productivity, **GMP** = Geometric mean productivity, **SSI** = Stress susceptibility index, **YI** = Yield index, **YSI =** Yield stability index, **YR** = Yield reduction ratio, **HM** = Harmonic mean and **DI** = Drought resistance index.

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization

For both traits seed cotton yield (table 09) and lint cotton yield (table 10), the first component (PC1) mostly was affected by Yp, Ys, STI, MP, GMP, HM, YSI, YI, and DI. Therefore, this component was related to yield potential and drought tolerance. The genotypes which have high value of PC1 are expected to have high yield under both stress and non-stress conditions. Similar results were reported by Isong, *et al.*, (2017). The most effective indices in the second component (PC2) were TOI, SSI and YR.

Evaluation of 12 cotton genotypes for seed cotton yield under drought stress conditions 99.82% of cumulative variations were justified by two first components and had latent roots more than one Table (09) and for lint cotton yield table (10) were 99.858% of cumulative variations . The first and second components had 91.041% and 8.779% variations, respectively. For seed cotton yield, first component had high positive coefficients for indices Yp (0.837), YS (0.998), STI (0.972), MP (0.967), GMP (0.979), HM (0.986), YSI (0.948), YI (0.998), and DI (0.994). Therefore, it was named seed cotton yield under both well-watered and drought stress conditions and detached tolerant genotypes with high yield. Second component had high positive coefficients including TOI (0.522), SSI (0.299) and YR (0.316). Therefore, this component was named as seed cotton yield under drought stress conditions and separated susceptible genotypes. For lint cotton yield, the first component had high positive coefficients for indices Yp (0.725), YS (0.999), STI (0.968), MP (0.962), GMP (0.976), HM (0.985), YSI (0.948), YI (0.999), and DI (0.990). Therefore, it was named lint cotton yield under both well-watered and drought stress conditions and detached tolerant genotypes with high yield. Second component had high positive coefficients including TOI (0.476), SSI (0.315) and YR (0.317). Therefore, this component was named as lint cotton yield under drought stress conditions and separated susceptible genotypes.

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Table 13: Principal components analysis of drought tolerance indices for lint cotton yield of 12 superior genotypes of two cotton crosses (G.93 × Menofy) and (G.96× C.B58) in 2018 growing season

Drought tolerance indices	**Component**	
	1	2
Yp	.725	.689
Ys	.999	.029
STI	.968	.248
MP	.962	.273
GMP	.976	.216
HM	.985	.169
TOI	-.879	.476
SSI	-.949	.315
YSI	.948	-.317
YR	-.948	.317
DI	.990	-.120
YI	.999	.029
Eigen value	10.755	1.228
Percent of variance	89.624	10.234
Cumulative percentage	89.624	99.858

Y_P = lint cotton yield under non-stress condition, **Y_S** = lint cotton yield under water stress condition, **STI** = Stress tolerance index, **TOL** = Tolerance index, **MP** = Mean productivity, **GMP** = Geometric mean productivity, **SSI** = Stress susceptibility index, **YI** = Yield index, **YSI =** Yield stability index, **YR** = Yield reduction ratio, **HM** = Harmonic mean and **DI** = Drought resistance index.

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization

Hence, it is concluded that first component was yield potential and second component was sensitive to stress Table (09) and table (10). Shakeel, *et al.,* (2018) experiment for identifying drought tolerant and susceptible genotypes with principal components analysis showed two components which explained 99.8% variations. Higher PCA1 and lower PCA2 scores produced high yielding genotypes.

6. B.1 – Fiber Quality

- **Fiber Length**

Plant breeders are employing PCA as a “pattern finding method” to complement cluster analysis Sajjad, *et al.,* (2011). The main advantage of using PCA over cluster analysis is that each statistics can be assigned to one group only (Khodadadi, *et al*., 2011). The purpose of principal components analysis is to obtain a small number of linear combinations of the 12 variables which account for most of the variability in the data. In this case, 2 components have been extracted, since 2 components had eigenvalues greater than or equal to 1.0 (Table 9).

The results of the principle component analysis (PCA) showed that the first two components explained 55 and 44.501% of the total variation (Table 7). In fact, by the method, twelve indices were reduced to two independent components. Eigen vectors in every component refer to the coefficients or the correlation between the component and the indices. In each component, a high correlation between the component and an index indicating that the index is associated with the direction of the maximum amount of variability in the data set. The first component (PC1) mostly was affected by Yp, Yp, TOI, SSI, and YR. Therefore, this component was related to yield potential and drought tolerance. The genotypes which have high value of PC1 are expected to have high yield under both stress and non-stress conditions. Similar results were reported by Golabadi, *et al.,* (2006) in durum wheat. The most effective indices in the second component (PC2) were STI, MP, GMP, HM, YSI, DI, and YI. Hence, PC2 is associated with yield under stress environment and stress susceptibility.

Evaluation of twelve genotypes under drought stress conditions 99.76% of cumulative variations were justified by two first components. The first and second components had 55% and 44.51% variations, respectively. First component had high positive coefficients for indices Yp(0.92), TOI (0.97), SSI(0.97), and YR(0.98). Therefore, it was named fiber length under both well-watered and drought stress conditions and detached tolerant

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genotypes with high fiber length. Second component had high positive coefficients including STI (0.88), MP(0.86), GMP(0.86), HM(0.89), DI(0.55), and YI(0.89) indices. Therefore, this component was named as fiber length under drought stress conditions and separated susceptible genotypes. Hence, it is concluded that first component was yield potential and second component was sensitive to stress (Table 7). At Zare, (2012) experiment for identifying drought tolerant and susceptible genotypes with principal components analysis showed two components which explained 99.76% variations.

Table 14: Principal components analysis of drought tolerance indices for fiber length trait of 12 superior genotypes of two cotton crosses (G.93 × Menofy) and (G.96× C.B58) in 2018 growing season.

Drought tolerance indices	**Component**	
	1	2
Yp	0.92	0.39
Ys	0.92	0.40
STI	0.46	0.88
MP	0.51	0.86
GMP	0.48	0.88
HM	0.46	0.89
TOI	0.97	-0.22
SSI	0.97	-0.24
YSI	-0.98	0.19
YR	0.98	-0.19
DI	-0.83	0.55
YI	-0.43	0.89
Eigen value	6.6	5.34
Percent of variance	55	44.51
Cumulative percentage	55	99.76

$\mathbf{Y_P}$ = fiber length under non-stress condition, $\mathbf{Y_S}$ = fiber length under water stress condition, **STI** = Stress tolerance index, **TOL** = Tolerance index, **MP** = Mean productivity, **GMP** = Geometric mean productivity, **SSI** = Stress susceptibility index, **YI** = Yield index, **YSI =** Yield stability index, **YR** = Yield reduction ratio, **HM** = Harmonic mean and **DI** = Drought resistance index.

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization

CONCLUSION

The results from this study are very useful for planning future cotton breeding programs especially in Egypt. The results obtained, it can be said that, drought stress indices STI, MP, GMP, YI, HM and DI were identify superior genotypes for water-stressed environments for seed cotton yield and lint cotton yield. And for fiber length drought stress indices STI, MP, GMP, and HM were identify superior genotypes. The genotypes G4, and G5 identified as tolerant to drought stress genotypes for seed cotton yield and lint cotton yield. Also The genotypes G6, G8, and G10 identified as tolerant to drought stress genotypes for fiber length. Spearman's rank correlation coefficient and principal component analysis identified STI, MP, GMP, YI, HM and DI as appropriate indices to select drought tolerance indices. Selection by these indices can be useful to identify genotypes with desirable for seed cotton yield and lint cotton yield in both well watering and water stress, and STI, MP, GMP, and HM for fiber length in both well watering and water stress.

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