Original Research Article

INVESTIGATE STABILITY AND GENOTYPES X ENVIRONMENTS ASSOCIATION IN EGYPTIAN COTTON GENOTYPES UNDER NORMALAND DROUGHT CONDITION UTILIZING GGE-BIPLOT MODEL

ABSTRACT

Drought stress is one of the most important abiotic stresses in plants. This investigation aimed to study the effect of drought stress on twenty four cotton genotypes belonging to ***Gossypium barbadense*** **L.**, ina randomized complete block design with three replications at Sakha Experimental Station, Agricultural Research Center, Kafr El-Sheikh government, Egypt, during fivegrowing seasons from 2016 to 2020 for the two treatments normal and drought. The normal irrigation treatment was done every fifteen days as recommended to receive eight irrigations during the growing season, while drought stress treatment received only four irrigations during the plant growth cycle. The studied traits were boll weight, seed cotton yield / plant, lint yield / plant and lint %. The four studied yield traits showed highly significant differences for genotypes, environments and G x E. These results indicated that the studied genotypes were differed in their responses under both treatments. Overall, the variation was mainly attributed to environments (20.921, 24.462, 26.975 and 32.549 %) followed by the genotypes (14.669, 8.509, 7.499 and 5.016 %) and GEI (11.934, 15.216, 13.726 and 9.004 %) for boll weight, seed cotton yield, lint yield and lint %, respectively.Phenotypic stability of the twenty four cotton genotypes was tested using GGE-biplot method across ten environments. Based on GEI and GG-biplot analysis, genotypes G5, G19 and G20 located in the mega-environments (E1, E3 and E5) were identified as the ideal genotypes with more stability and higher lint cotton yield production.

Keywords: cotton, yield, drought stress, stability, GEI, GGE-biplot.

INTRODUCTION

Cotton, the leading natural fiber crop both worldwide andin Egypt, suffers from inadequate water supplies in manyregions and rapid climatic changes, resulting in low yield.Cotton production fluctuates substantially because of abiotic and biotic stresses. Among the abiotic stresses, drought is recognized as the most devastating which limits the cotton production markedly. Drought stress significantly reduces crop production by affecting many agronomic traitslike reduction in size and number of bolls / plant, plant height, above ground fresh weight, seed cotton yield, seed index and fiber quality traits. For successful of conventional cotton breeding program for drought, the breeder should know the basic information about available breeding material. Firstly, there must be significant variability between genotypes responses under drought stress and secondly, the genetically controlled of this variation. Thus, an understanding of the knowledge of these two components about the breeding material under consideration is necessary to establish a breeding program for drought.

There is thus a need to improve cottonwith respect to drought tolerance to sustain production in Egypt. Breeding to improve drought-tolerant genotypes requiresidentification of physiological mechanisms and morphological traits conferring drought tolerance**AbdEl-Moghny*et al.*, 2017**.The prerequisite for successrequires determination of the extent of genotypic variationwithin a species for these traits, and their relative contribution to economic. Also, a wide range of responses at molecular, cellular and wholeplantlevels have been determined in plants that aid in tolerancefor drought stress (**Abdelmoghny*et al.*, 2020**).**Payton *et al*., 2004** reported that whenwater was withheld on cotton plant at flowering stage for seven days, most of the bolls that were at elongation phase abscised and those that did not abscise were found to have drastically reduced size.**Kar *et al*. 2001**showed that yield and itscomponents decreased significantly in all the varieties under the studyas a deficit of water stress imposed at flowering stage. The flowering stage in cotton was found to be the critical stage to moisture stress. Significant genotypic difference for physiological attributes and seed cotton yield existed under both irrigated and water stress conditions.

GGE-biplot was recommended as the most appropriate stability analysis to evaluate the genotype performance under different environments.**Yan *et al.*, 2007**reported that genotype main effects should be integrated with genotype into environment interaction (GEI) for evaluation of genotypes under different environments using GGE-biplot analysis as described by **Yan and Kang, 2003**. Environment is evaluated for discrimination ability (ability to differentiate between genotypes), representativeness (ability to represent the target region) and desirability index (distance from ideal location) (**Yan, 2001; Yan 2002; Yan and Tinker 2005**). GGE-biplot is also used for evaluation of genotypes for average performance and stability.

The aim of this study was to evaluate twenty four barbadense cotton genotypes of genetic variability under drought stress in experimental field trails during five growing seasons to estimate the effect on four yield traits. Then the study extended to estimate stability through these genotypes using GGE-biplot method.

MATERIALS AND METHODS

Twenty four cottongenotypes belonging to ***Gossypium barbadense*** **L.**as shown in **Table 1**were obtained from obtaining from thegenbank of Cotton Breeding Sector, Cotton Research Institute, Agricultural Research Center, Egypt. Two experimental fields were conduct at Sakha Experimental Station, Agricultural Research Center, Kafr El-Sheikh government, Egypt, during fivegrowing seasons from 2016 to 2020.

Twenty four cotton genotypes were evaluated under two irrigationregimesina randomized complete block design with three replications for each treatment normal and drought stress.Each experimental plot consists offive rows and the genotypes were plantedunder the standard agronomic practices following proper plantgeometry with 4 m row length, 70 cm x30 cm row to row andplant to plant spacing, respectively. Finally the plot size was 13 m^2 at each growing seasons. Allagronomic and cultural practices were done manually and regularlyduring the five growing seasons, except irrigation treatment.The experiment was divided to two irrigation treatments normal and drought stress. The normal treatment received eight irrigations during the growing season as the recommended rules, while the drought treatment received only four irrigations during the growing season though the five growing seasons. To delete the border effects, sampling was made on three middlerows to estimate seed cotton yield / plot (SCY/P) and lint cotton yield / plot (LY/P) after ginning process in grams. While, fifty bolls were collected from the outer two rows to estimate average boll weight (BW) in grams.

Before the combined analysis of variance, the variance homogeneityof experimental errors was examined by Bartlett's test.The analysis of variance (ANOVA) explained to partition the variations due to the effect of genotypes, years, environments and their interaction, also significant difference within these factors was estimated using LSDtest at P = 0.05 and 0.01 probability level according to **Gomez and Gomez, 1984**.

The GGE-biplot was constructed based on the first two principalcomponents (PCs) resulting from singular value decomposition(SVD), by estimating each element of the matrix through, also the multivariate graphical technique of GGE biplot was used to determine the stable genotypesfollowing formulas described by **Yan *et al.*, 2000; Yan and Kang, 2003.**

$$Y_{ij} = \mu + e_j + \sum_{n=1}^{N} \lambda_n \gamma_{in} \delta_{jn} + \varepsilon_{ij}$$

Y_{ij} = mean response of ith genotype (i = 1,...,I) in the j^{th} environment (j = 1,..,J).

μ = grand mean.

e_j = environment deviations from the grand mean.

λ_n = the Eigen value of PC analysis axis.

$\gamma_{in}$and δ_{jn} = genotype and environment PCsscores for axis n.

N = number of PCs retained in the model.

ε_{ij} = residual effectN $(0,\sigma^2)$.

GenStat version 17^{th}statistical package software was used to generate the E and G×E interaction biplot used to analyze the multi-environment trial (MET) data.Bartlett's test and combined analysis of variance for data and GGE-biplot based on five patterns: (a)determining the best genotype in each environment, (b) coordinatesof average environment, (c) ranking the genotypes based on the idealgenotype, (d) ranking the environments based on the ideal environment,and (e) examining the relationship among the environmentswas used for graphical analysis.

Table 1: Origin and pedigree of the twenty four cotton genotypes under study

No.	Genotypes	Pedigree	Origin
G1	**Giza 89**	Giza 89 x 6022	**Egypt**
G2	**Z101**	Unknown	Unknown
G3	**Giza 85**	Giza 67 x CB58	**Egypt**
G4	**Giza 75**	Unknown	**Egypt**
G5	**Giza 94**	10229 x Giza 86	**Egypt**
G6	**A106**	Unknown	Unknown
G7	**A101**	Unknown	Unknown
G8	**Z102**	Unknown	Unknown
G9	**Giza 89 x Giza 86**	Unknown	**Egypt**
G10	**Giza 45**	Giza 28 x Giza 7	**Egypt**
G11	**A108**	Unknown	Unknown
G12	**Giza 93**	Giza 77 x S106	**Egypt**
G13	**D101**	Unknown	Unknown
G14	**Giza 70**	Giza 59A x Giza 51B	**Egypt**
G15	**A105**	Unknown	Unknown
G16	**G102**	Unknown	Unknown
G17	**R101**	Unknown	Unknown
G18	**G101**	Unknown	Unknown
G19	**Giza 96**	(Giza 84 x (Giza 70 x Giza 51B)) x S62	**Egypt**
G20	**Giza 86**	Giza 75 x Giza 81	**Egypt**
G21	**Giza 95**	(Giza 83 x (Giza 75 x 5844)) x Giza 80	**Egypt**

G22	**S106**	Unknown	Unknown
G23	**S107**	Unknown	Unknown
G24	**S109**	Unknown	Unknown

RESULTS AND DISCUSSIONS

The data was tested for uniformity of variance. Then, combined analysis of variance based on randomized complete block design (RCBD) was performed as shown in **Table 2**. The results showed that the effect of genotype (G), environments (E), and G x Efor all the studied traits were significant at 1% probability level, indicating the existence of genetic variability for these genotypes.While, the significance of GEI indicated that these genotypes had different phenotypic response under these environmental conditions. These results are in harmony with **Yan and Falk 2002 ; Yan and Rajcan 2002 ;Shaker *et al.*, 2019;Abdelmoghny*et al.*, 2019 and 2020** for different Egyptian cotton genotypes.Overall, the variation was higher for environments followed by genotypes then genotype x environment interaction (GEI). The variation was mainly attributed to environments (20.921, 24.462, 26.975 and 32.549 %) followed by genotypes (14.669, 8.509, 7.499 and 5.016 %) and GEI (11.934, 15.216, 13.786 and 9.004 %) for boll weight, seed cotton yield, lint yield and lint %, respectively. Highly significant GEI for the four studied yield traits indicated that the breeder could analyze adaptability and stability as the factors had the greatest influence on genotypes.

The concerning mean performance data of the studied twenty four cotton genotypes over ten environments during five growing seasons for boll weight, seed cotton yield, lint yield and lint % traits are presented in **Tables 3,4, 5 and 6,** respectively. Genotype by environment study was carried out for 24 cotton genotypes by growing in five consecutive normal cotton growing seasons from 2016 to 2020 under ten environments.Mean performance for the four studied yield traits along with environments mean indicated that thegenotypes have high variation around the overall mean.On average the genotypes revealed higher boll weight, seed cotton yield per plant, lint yield per plant and lint % under E1, E2, E3, E4 and E5 the other environments (E6, E7, E8, E9 and E10), which also confirmed the major share of variation by environments.

For boll weight (BW) trait the environmental mean ranged from 2.63 g to 3.16 g for E10 and E3, respectively. While, the average genotypes mean performance was 3.13 g and 2.69 g the first five environments (E1, E2, E3, E4 and E5) and the second five environments (E6, E7, E8, E9 and E10), respectively as shown in **Table 3**.However, maximum boll weight was recorded for genotypes G2, G7, G8, G9, G13 and G 14 (3.17, 3.33, 3.01, 3.15 and 3.33g, respectively) overall the ten environments. While, seed cotton yield per plant (SCY/P) the environmental mean performance was ranged from 154.89g for E3 to 72.80g for E10. Four cotton genotypes had the highest seed cotton yield production G5, G18, G19 and G20 produce 178.50, 120.19, 138.54 and 143.10, respectively overall the studied environments as presented in **Table 4**.

The lint cotton yield per plant (LY/P) the environmental mean was ranged from 35.60g to 58.54g for G10 and G3, respectively. Nine cotton genotypes produce higher lint cotton yield per plant more the overall mean performance (40.70g). These genotypes were G1,G2, G5, G15, G17, G18, G19, G20 and G21 was 43.14, 40.71, 65.03, 42.72 40.78, 45.01, 50.67, 52.64 and 41.07 g, respectively as illustrated in **Table 5**.On the other hand, lint percentage (L%) the environmental mean was ranged from 34.38 % to 38.79 % for E1 to E9, respectively. Ten cotton genotypes (G1, G2, G6, G8, G13, G15, G17, G18, G20 and G22) had higher lint percentage (L %) 36.95 %, 37.35 %, 37.06 %, 36.48 %, 37.21 %, 36.71 %, 36.83 %, 36.56 % and 36.43 %, respectively more than the overall mean performance (36.18%) as shown in **Table 6**.All these findings which reflected the differences between the twenty four cotton genotypes across the ten environments might be due to their genetic potential and the environment factors. Also, these results are in conformed by the analysis of variance which showed highly significant between these genotypes across ten studied environments.The similar results were obtained by **El-Shaarawy*et al* 2007;Abdelmoghny*et al*, 2019** and **2020** and **Shaker*et al*., 2019** for different Egyptian cotton genotypes under different environments.

In case of correlation between studied four yield traits (boll weight, seed cotton yield, lint yield and lint %)as shown in **Table 7**. The highlysignificant positive association between seed cotton yield and lint yield under both treatments. While, under this investigation the correlation between boll weight, lint yield and lint % was non-significant. On the other hand, many researchers found that there is apositive and highly significant correlation between yield traits. **Al-Hibbiny*et al*., 2019; El-Mansy*et al*., 2020** and **Gibely, 2021** found highly significant positive correlation between yield traits among different Egyptian cotton genotypes.

Table 2: Combined analysis of variance for the twenty four cotton genotypes under ten environmentsduring five growing seasons

S.O.V	d.f	Boll weight	Total of variation %	Seed cotton yield / plant	Total of variation %	Lint yield / plant	Total of variation %	Lint percentage	Total of variation %
Replications	**2**	0.343		88.774		13.685		0.241	
Treatments	**239**	0.34	47.520	5272.439	48.187	818.645	48.261	8.005	46.568
Environments	**9**	4.068	20.921	71077.051	24.462	12151.285	26.975	148.518	32.549
Genotypes	**23**	1.114	14.669	9674.318	8.509	1321.891	7.499	8.955	5.016

G x E	**207**	0.108	11.934	1922.26	15.216	270.000	13.786	1.782	9.004
Error	**478**	0.016		197.973		29.447		0.586	
Coefficient of variation %		**4.435**		**12.739**		**13.389**		**2.116**	

Table 3: Mean performance for boll weight (g) under normal and drought stress for the twenty four cotton genotypes

Genotypes	Normal					G mean	Drought					G mean	Overall mean
	E1	E2	E3	E4	E5		E6	E7	E8	E9	E10		
G1	3.11	2.94	3.19	2.91	2.92	**3.01**	2.82	2.88	2.81	2.68	2.51	**2.74**	**2.88**
G2	3.50	3.55	3.50	3.30	3.39	**3.45**	3.12	3.16	2.95	2.64	2.59	**2.89**	**3.17**
G3	3.11	3.06	3.10	3.02	2.98	**3.06**	2.82	3.08	3.00	2.66	2.69	**2.85**	**2.95**
G4	3.00	2.99	2.83	3.01	3.04	**2.97**	2.81	3.01	2.76	2.74	2.92	**2.85**	**2.91**
G5	3.00	3.03	3.09	3.29	3.26	**3.13**	2.21	2.77	2.51	2.70	2.22	**2.48**	**2.81**
G6	3.19	3.20	3.17	2.95	2.90	**3.08**	2.91	3.04	2.76	2.21	2.68	**2.72**	**2.90**
G7	3.52	3.51	3.48	3.54	3.43	**3.50**	3.29	3.39	3.22	2.79	3.16	**3.17**	**3.33**
G8	3.38	3.35	3.29	3.29	3.26	**3.32**	3.06	3.12	2.90	3.28	2.91	**3.06**	**3.19**
G9	3.09	3.14	3.24	3.11	3.08	**3.13**	2.92	3.00	2.81	3.03	2.62	**2.88**	**3.01**
G10	3.07	3.08	3.06	3.34	3.15	**3.14**	2.52	2.68	2.50	2.73	2.44	**2.57**	**2.86**
G11	2.99	2.98	3.57	3.26	3.32	**3.23**	2.67	2.80	2.63	2.52	2.99	**2.72**	**2.97**
G12	3.21	3.32	3.41	2.94	3.17	**3.21**	2.98	3.12	2.94	3.00	2.45	**2.90**	**3.05**
G13	3.32	3.12	3.24	3.53	2.89	**3.22**	3.22	3.34	3.09	2.61	3.12	**3.08**	**3.15**
G14	3.15	3.33	3.19	3.24	3.49	**3.28**	2.97	2.89	2.78	3.23	2.88	**2.95**	**3.12**
G15	3.27	3.24	3.00	2.98	3.26	**3.15**	2.29	2.41	2.40	2.99	2.26	**2.47**	**2.81**
G16	3.09	2.96	3.05	3.14	2.97	**3.04**	2.77	2.49	2.69	2.29	2.86	**2.62**	**2.83**
G17	3.10	3.05	3.55	2.91	3.13	**3.15**	2.36	2.34	2.48	2.90	2.51	**2.52**	**2.83**
G18	3.55	3.60	3.04	2.97	2.83	**3.20**	2.27	2.38	2.25	2.36	2.40	**2.33**	**2.77**
G19	3.11	3.14	3.21	2.95	2.87	**3.06**	2.43	2.51	2.51	2.27	2.50	**2.44**	**2.75**
G20	3.24	3.09	2.79	2.98	2.94	**3.01**	2.93	2.71	2.68	2.43	2.71	**2.69**	**2.85**
G21	2.88	2.85	2.97	3.03	2.97	**2.94**	2.23	2.20	2.21	2.87	2.26	**2.35**	**2.65**
G22	3.07	3.04	2.97	2.92	3.06	**3.01**	2.27	2.39	2.30	2.23	2.28	**2.29**	**2.65**
G23	2.97	3.02	2.95	2.88	3.05	**2.97**	2.38	2.42	2.41	2.27	2.41	**2.38**	**2.68**
G24	2.93	2.93	2.91	2.98	2.89	**2.93**	2.66	2.71	2.68	2.38	2.63	**2.61**	**2.77**
E mean	**3.16**	**3.15**	**3.16**	**3.10**	**3.09**	**3.13**	**2.70**	**2.79**	**2.68**	**2.66**	**2.63**	**2.69**	**2.88**
Mean E	**3.13**						**2.69**						**2.91**
LSD at	**0.05**						**0.01**						
Environments	**0.042**						**0.054**						
Genotypes	**0.063**						**0.089**						
G x E	**0.207**						**0.277**						

Table 4: Mean performance for seed cotton yield / plant (g) trait under normal and drought stress for the twenty four cotton genotypes

Genotypes	Normal					G mean	Drought					G mean	Overall mean
	E1	E2	E3	E4	E5		E6	E7	E8	E9	E10		
G1	101.60	105.30	108.96	189.72	221.83	**145.48**	65.13	78.14	84.11	90.81	111.54	**85.95**	**115.71**
G2	129.03	136.41	127.98	113.79	132.60	**127.96**	77.01	94.68	88.60	108.41	75.28	**88.80**	**108.38**
G3	117.26	137.87	140.35	138.65	140.99	**135.03**	64.53	81.62	82.50	73.93	47.09	**69.93**	**102.48**
G4	128.17	131.11	130.69	112.09	120.94	**124.60**	111.85	124.97	128.13	66.16	78.80	**101.98**	**113.29**
G5	267.50	259.07	250.90	246.97	243.33	**253.55**	102.52	130.37	109.21	81.30	93.89	**103.46**	**178.50**
G6	114.86	126.30	145.64	100.29	105.38	**118.49**	88.72	106.68	100.96	104.57	85.84	**97.36**	**107.92**
G7	155.02	164.89	155.83	84.83	98.74	**131.86**	78.35	110.54	79.53	82.80	55.25	**81.29**	**106.58**
G8	116.76	116.32	122.53	108.17	120.03	**116.76**	80.91	92.25	89.15	55.61	82.27	**80.04**	**98.40**
G9	139.86	148.99	143.83	101.55	108.00	**128.45**	78.80	93.41	85.88	82.74	77.67	**83.70**	**106.07**
G10	129.44	138.14	134.40	73.54	141.03	**123.31**	69.41	84.97	86.46	78.07	57.70	**75.32**	**99.31**
G11	124.38	130.61	164.26	91.20	83.96	**118.88**	72.83	96.32	78.82	63.70	55.66	**73.47**	**96.17**
G12	171.13	177.16	186.39	68.66	97.28	**140.12**	50.03	81.65	61.94	63.37	49.53	**61.30**	**100.71**
G13	168.29	107.47	103.55	80.45	87.18	**109.39**	76.14	68.42	65.76	46.20	60.83	**63.47**	**86.43**
G14	106.90	183.77	200.04	95.78	84.22	**134.14**	93.19	107.40	96.47	63.36	54.60	**83.00**	**108.57**
G15	184.11	192.98	131.25	90.28	96.67	**139.06**	94.13	107.23	109.60	53.81	80.72	**89.10**	**114.08**
G16	130.55	132.40	142.90	96.33	96.48	**119.73**	97.00	104.74	103.71	76.67	57.99	**88.02**	**103.87**
G17	139.19	137.47	182.77	101.27	102.98	**132.74**	93.42	103.31	98.68	55.65	85.10	**87.23**	**109.98**
G18	181.21	186.82	202.74	90.89	102.90	**152.91**	98.01	107.16	98.27	83.39	57.74	**88.91**	**120.91**
G19	203.79	196.74	206.18	112.26	96.60	**163.12**	133.96	162.30	116.59	58.79	98.19	**113.97**	**138.54**
G20	206.18	212.45	129.94	119.06	137.33	**160.99**	128.57	154.86	146.96	91.84	103.80	**125.21**	**143.10**
G21	129.79	130.25	143.92	97.60	135.99	**127.51**	93.22	106.80	101.34	97.72	86.17	**97.05**	**112.28**
G22	128.88	123.64	138.83	77.15	106.52	**115.00**	75.72	96.43	82.08	75.66	50.87	**76.15**	**95.58**
G23	144.33	147.75	133.79	67.01	85.97	**115.77**	65.50	78.11	91.07	50.63	59.70	**69.00**	**92.39**
G24	126.88	128.91	189.72	105.38	76.96	**125.57**	71.18	94.23	90.81	52.22	80.93	**77.87**	**101.72**
E mean	**147.71**	**152.20**	**154.89**	**106.79**	**117.66**	**135.85**	**85.84**	**102.78**	**94.86**	**73.23**	**72.80**	**85.90**	**115.71**
Mean E	**135.85**						**85.90**						**110.88**
LSD at 0.05	**0.05**					**0.01**							
Environments	**4.593**					**6.048**							
Genotypes	**7.125**					**9.354**							
G x E	**22.512**					**29.591**							

Table 5: Mean performance for lint yield / plant (g) trait under normal and drought stress for the twenty four cotton genotypes

Genotypes	Normal					G mean	Drought					G mean	Overall mean
	E1	E2	E3	E4	E5		E6	E7	E8	E9	E10		
G1	39.63	39.40	40.14	74.50	83.77	**55.49**	23.50	28.43	29.97	31.86	40.23	**30.80**	**43.14**
G2	50.49	51.65	50.47	44.05	49.57	**49.25**	27.65	34.90	31.91	39.50	26.92	**32.17**	**40.71**
G3	46.58	53.48	53.03	50.51	51.65	**51.05**	21.76	29.60	28.26	26.43	16.05	**24.42**	**37.73**
G4	49.29	49.69	49.65	40.56	43.68	**46.57**	39.35	45.70	45.43	22.17	27.63	**36.05**	**41.31**
G5	102.23	97.13	95.43	89.49	87.71	**94.40**	35.24	45.91	37.57	26.80	32.78	**35.66**	**65.03**
G6	45.66	46.54	54.79	37.15	38.17	**44.46**	31.81	38.39	36.01	35.70	30.60	**34.50**	**39.48**
G7	59.73	60.66	58.27	30.62	35.56	**48.97**	26.61	40.01	27.83	29.36	19.30	**28.62**	**38.80**
G8	45.61	43.84	46.15	41.10	44.78	**44.30**	29.84	34.72	32.65	18.69	29.68	**29.12**	**36.71**
G9	55.10	56.46	52.75	36.50	38.32	**47.82**	26.85	32.20	29.93	29.94	26.47	**29.08**	**38.45**
G10	49.80	50.87	50.09	25.72	52.16	**45.73**	23.08	29.14	29.95	26.22	18.88	**25.45**	**35.59**
G11	48.10	48.85	62.06	32.74	29.06	**44.16**	24.66	33.76	27.18	20.92	19.02	**25.11**	**34.64**
G12	65.41	67.03	67.95	24.24	34.49	**51.82**	16.78	28.39	21.49	21.13	17.23	**21.00**	**36.41**
G13	63.87	40.86	39.04	30.59	30.99	**41.07**	27.37	25.05	23.43	15.27	22.08	**22.64**	**31.85**
G14	42.21	67.13	75.50	36.49	30.56	**50.38**	33.92	38.59	34.68	22.42	19.35	**29.79**	**40.08**
G15	71.99	72.89	49.00	34.43	35.96	**52.85**	34.84	39.27	40.02	19.39	29.40	**32.58**	**42.72**
G16	49.95	49.81	54.92	35.15	36.36	**45.24**	33.34	36.76	36.48	27.72	20.22	**30.90**	**38.07**
G17	54.50	52.82	69.15	36.94	36.84	**50.05**	34.46	38.62	35.98	18.84	29.62	**31.50**	**40.78**
G18	71.83	68.93	76.59	33.74	37.32	**57.68**	37.11	39.70	36.73	27.82	20.29	**32.33**	**45.01**
G19	79.37	73.99	78.30	40.75	34.99	**61.48**	46.70	57.40	40.65	19.86	34.64	**39.85**	**50.67**
G20	80.08	79.24	49.14	44.23	49.73	**60.48**	46.41	55.99	53.15	31.63	36.75	**44.79**	**52.64**
G21	51.65	49.59	55.09	35.13	50.26	**48.35**	31.95	37.81	35.49	33.59	30.15	**33.80**	**41.07**
G22	50.49	47.00	53.00	28.71	37.97	**43.43**	27.07	34.18	29.04	25.60	18.13	**26.80**	**35.12**
G23	56.34	55.75	49.97	24.15	31.37	**43.52**	21.86	26.10	31.18	17.79	20.50	**23.48**	**33.50**
G24	49.66	47.37	74.50	39.63	27.42	**47.72**	24.97	32.84	31.86	17.16	28.37	**27.04**	**37.38**
E mean	**57.48**	**57.12**	**58.54**	**39.46**	**42.86**	**51.09**	**30.30**	**36.81**	**33.62**	**25.24**	**25.60**	**30.31**	**43.14**
Mean E	**51.09**						**30.31**						**40.70**
LSD at	**0.05**					**0.01**							
Environments	**1.775**					**2.326**							
Genotypes	**2.74**					**3.6**							
G x E	**8.687**					**11.419**							

Table 6: Mean performance for lint percentage (L %) trait under normal and drought stress for the twenty four cotton genotypes

Genotypes	Normal					G mean	Drought					G mean	Overall mean
	E1	E2	E3	E4	E5		E6	E7	E8	E9	E10		
G1	39.01	37.41	36.84	39.27	37.76	**38.06**	36.08	36.38	35.63	35.08	36.07	**35.85**	**36.95**
G2	39.13	37.87	39.44	38.71	37.38	**38.50**	35.90	36.86	36.02	36.44	35.75	**36.19**	**37.35**
G3	39.72	38.79	37.79	36.43	36.64	**37.87**	33.71	36.27	34.25	35.75	34.08	**34.81**	**36.34**
G4	38.46	37.90	37.99	36.18	36.12	**37.33**	35.18	36.57	35.46	33.51	35.06	**35.15**	**36.24**
G5	38.22	37.49	38.03	36.23	36.04	**37.20**	34.37	35.22	34.40	32.96	34.92	**34.37**	**35.79**
G6	39.75	36.85	37.62	37.05	36.22	**37.50**	35.86	35.99	35.66	34.14	35.65	**35.46**	**36.48**
G7	38.53	36.79	37.39	36.10	36.01	**36.97**	33.96	36.20	34.99	35.45	34.93	**35.11**	**36.04**
G8	39.06	37.69	37.66	38.00	37.31	**37.95**	36.88	37.64	36.63	33.61	36.08	**36.17**	**37.06**
G9	39.39	37.89	36.67	35.94	35.48	**37.08**	34.07	34.47	34.85	36.18	34.09	**34.73**	**35.90**
G10	38.48	36.82	37.27	34.97	36.99	**36.91**	33.25	34.30	34.64	33.59	32.72	**33.70**	**35.30**
G11	38.68	37.40	37.78	35.90	34.61	**36.87**	33.86	35.05	34.48	32.84	34.17	**34.08**	**35.48**
G12	38.22	37.83	36.46	35.31	35.46	**36.66**	33.53	34.77	34.69	33.35	34.78	**34.22**	**35.44**
G13	37.95	38.02	37.70	38.02	35.55	**37.45**	35.95	36.61	35.63	33.06	36.30	**35.51**	**36.48**
G14	39.48	36.53	37.74	38.10	36.29	**37.63**	36.40	35.93	35.94	35.38	35.44	**35.82**	**36.72**
G15	39.10	37.77	37.33	38.14	37.20	**37.91**	37.01	36.63	36.51	36.03	36.42	**36.52**	**37.21**
G16	38.26	37.62	38.43	36.50	37.68	**37.70**	34.37	35.10	35.17	36.16	34.86	**35.13**	**36.42**
G17	39.16	38.43	37.84	36.48	35.77	**37.53**	36.88	37.38	36.46	33.86	34.81	**35.88**	**36.71**
G18	39.64	36.90	37.78	37.12	36.27	**37.54**	37.86	37.04	37.38	33.36	35.15	**36.16**	**36.85**
G19	38.94	37.61	37.98	36.29	36.22	**37.41**	34.86	35.37	34.87	33.78	35.28	**34.83**	**36.12**
G20	38.84	37.30	37.81	37.15	36.21	**37.46**	36.10	36.16	36.17	34.45	35.41	**35.66**	**36.56**
G21	39.80	38.08	38.27	36.00	36.96	**37.82**	34.27	35.40	35.02	34.38	34.99	**34.81**	**36.32**
G22	39.18	38.02	38.17	37.22	35.64	**37.64**	35.74	35.45	35.38	33.84	35.64	**35.21**	**36.43**
G23	39.03	37.74	37.35	36.04	36.49	**37.33**	33.37	33.41	34.24	35.13	34.33	**34.10**	**35.71**
G24	39.14	36.75	39.27	37.61	35.63	**37.68**	35.08	34.85	35.08	32.86	35.06	**34.58**	**36.13**
Mean E	**38.97**	**37.56**	**37.78**	**36.86**	**36.33**	**37.50**	**35.19**	**35.79**	**35.40**	**34.38**	**35.08**	**35.17**	**36.95**
Mean E	**37.50**						**35.17**						**36.33**
LSD at	**0.05**						**0.01**						
Environments	**0.256**						**0.323**						
Genotypes	**0.382**						**0.512**						
G x E	**1.227**						**1.616**						

Table 7: Correlation between studies four yield traits under normal condition (above diagonal) and under drought stress (blow diagonal)

Traits	Boll weight g	Seed cotton yield g	Lint yield g	Lint %
Boll weight	1	-0.031	-0.037	-0.041
Seed cotton yield	-0.276	1	0.999**	-0.117
Lint yield	-0.247	0.994**	1	-0.074
Lint %	0.146	0.268	0.374	1

GGE biplot analysis (Polygon view):

Which–won–where or which–is–best for what analysis

Studying the which–won–where pattern of multi environment yield trails is important for the possible existence of different mega–environment in a region as reported by **Yan *et al,* 2000 and 2001**.The results of GGE-biplot had 53.86% and 28.85% for PCA 1 and PCA 2, respectively with the total variation of 82.44% for lint yield. Similar results showed higher environmental effect on lint cotton yield on the Egyptian cotton genotypes are obtained by

Abd El-Moghny and Max, 2015,Shaker *et al*., 2019 and Abdelmoghny*et al*., 2020.**Figure 1**showa polygon vertexconnecting the genotypesG1, G5, G23, G12, G15 and G19, the furthest genotypes from the biplot point of origin wereused to make the perpendicular.These genotypes have the longest vectors in their respective directions; the vector length and direction represents the extension of the genotypes response to the tested environments. All other genotypes are contained within the polygon and have smaller vectors.All the remaining genotypes are contained within the polygon that has the smallest vectors. These results indicatedless sensitive to interaction with the environment in each sector. The vectors from the center of origin of the biplot divide the graph into eight sectors.The important result of this feature for this view of GGE-biplot is that the top genotypes for each sector has the highest yield than the other genotypes in all environments that fall in the sector (**Yan, 2002**).The biplot classified the ten environments into four mega-environments. Genotypes G5, G15, G18, G19 and G20 are located in the mega-environments (E2, E4 and E6). So, these genotypes will produce high lint yield (g) in these environments.On the other hand, the top genotypes without any environments in their sectors were not the highest yielding genotypes at any environments, but they were the poorest on some environments. Similar results were observed by**Shaker*et al*.,2019 and Abdelmoghny*et al*., 2020** observed five and six sectors of graph division when assessing lint yield trait of some Egyptian cotton genotypes using the GGE-biplot method, respectively.

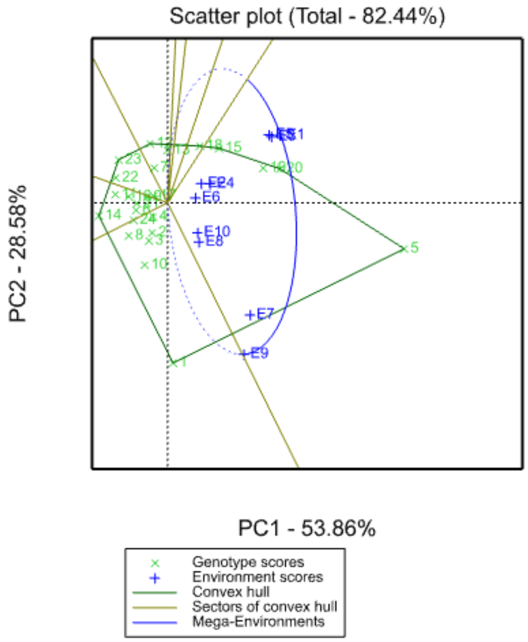

Figure 1:Polygon view of the GGE-biplot for the which – one – where pattern for genotypes and environments

Yield performance and stability of genotypes

The genotypes were evaluated by the average environment coordination (AEC) method, the average environment is defined by the average PC1 and PC2 scores of all environments, which represented by the small circle as presented in **Figure 2**. The line was passing through this average environments and biplot origin point is the average environment axis serves as the abscissa of the AEC.The stability and suitability was estimated through the projection of the corresponding cultivar along the AEC axis. **Yan and Kang, 2002** reported that the genotypes fall to the right side of this axis has higher yield productivity, while the genotypes falling on the left side had less yield productivity and stability estimated by the two arrows that are perpendicular. So, the genotypes which close to the axis is the more stable genotype, while the genotypes which far from this axis are not stable. The GGE-biplot method help breeder to select the most stable genotype which had the highest yield productivity (**Figure 2**). Thus, G5, G19 and G20 were identified as the most stable and higher lint yield (g) whereas G7, G10, G12, G13 and G8 was found atthe left side which know as the lower yield genotypes and least stable.

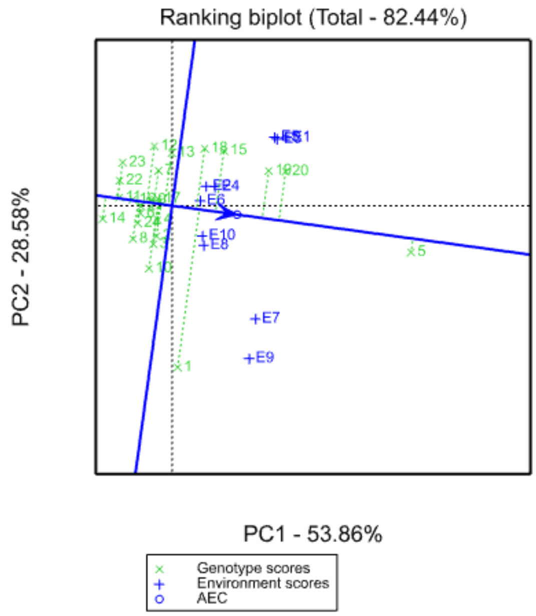

Figure2: Average environment coordination (AEC) views of the GGE-biplot based on genotype for ranking and stability of genotypes

Ideal genotypes and ideal environment

GGE-biplot used to identify and evaluate the ideal genotypes and the ideal environments. The ideal genotype is located in the first concentric circle of the biplot, while the nearest genotypes to the ideal genotype were the desirable ones (**Yan and Kang, 2003**). In this study, G5 was the ideal genotype over the twenty four genotypes under the study. While, G19 and G20 were close to the ideal genotype and located in the second concentric circle were the desirable ones as shown in **Figure 3**. While, genotypes G2, G6, G8, G11,G12, G14, G22 and G24 were the undesirable genotypes because they were at distant from the first concentric circle.The environment located in the first concentric circle in the biplot termed known as the ideal environment and the environments located close to the ideal environment considered as the desirable environments. In present study, E1, E3 and E5 are located in first concentric circle followed by E7 and those environments which are close to the ideal environments are desirable environments as presented in **Figure 4**.

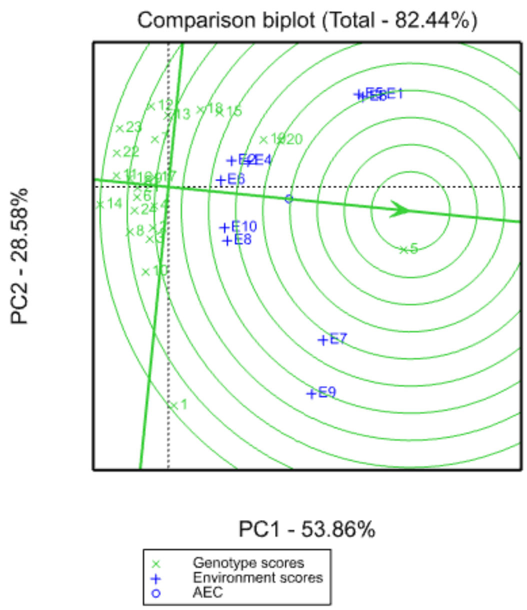

Figure 3: GGE-biplot with scaling focused on genotypes

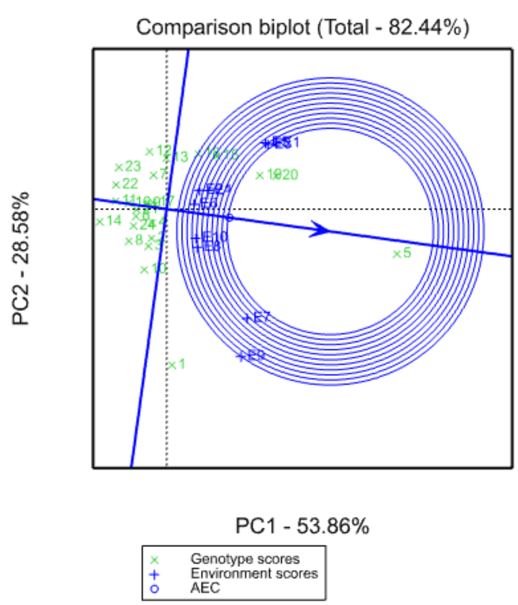

Figure 4: GGE-biplot with scaling focused on environments

CONCLUSION

The present study indicated that cotton lint yield was a good indicator to select the highest genotypes under different environments. Experiments across different years, locations will enable to identify the effect of the mega environments. The analysis of variance for the lint cotton yield indicated that genotypes, environments,GE interaction was highly significant.Itshowed that the GE interaction was an importantsource of cotton lint yield variation and its biplot werethe powerful for visualizing the response patterns ofgenotypes and environments.The GGE-biplot method was concordant in discriminating environments and genotypes for phenotypic stability. The genotypes G5, G19 and G20 achieved high lint cotton yield and phenotypic stability in environments (E1, E3 and E5).

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