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INVESTIGATE STABILITY AND GENOTYPES X ENVIRONMENTS ASSOCIATION IN EGYPTIAN COTTON GENOTYPES UNDER NORMAL AND DROUGHT CONDITION UTILIZING GGE-BILOT 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., in a randomized complete block design with three replications at Sakha Experimental Station, Agricultural Research Center, Kafr El-Sheikh government, Egypt, during five growing 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, 13.786 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.

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INTRODUCTION

3 Cotton, the leading natural fiber crop both worldwide and in Egypt, suffers from
inadequate water supplies in many regions 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 traits like 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.

16 There is thus a need to improve cotton with respect to drought tolerance to sustain
production in Egypt. Breeding to improve drought-tolerant genotypes requires identification
of physiological mechanisms and morphological traits conferring drought tolerance **Abdel-
Moghaib et al., 2017**. The prerequisite for success requires determination of the extent of
genotypic variation within a species for these traits, and their relative contribution to
economic. Also, a wide range of responses at molecular, cellular and whole plant levels have
been determined in plants that aid in tolerance for drought stress (**Abdelmoghaib et al.,
2020**). **Payton et al., 2004** reported that when water 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 its components decreased significantly in all the varieties under the study as 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.

30 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 a and b). 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.

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MATERIALS AND METHODS

Twenty four cotton genotypes belonging to *Gossypium barbadense* L. as shown in Table 1 were obtained from the genbank of Cotton Breeding Sector, Cotton Research Institute, Agricultural Research Center, Egypt. Two experimental fields were conducted at Sakha Experimental Station, Agricultural Research Center, Kafr El-Sheikh government, Egypt, during five growing seasons from 2016 to 2020.

Twenty four cotton genotypes were evaluated under two irrigation regimes in a randomized complete block design with three replications for each treatment normal and drought stress. Each experimental plot consists of five rows and the genotypes were planted under the standard agronomic practices following proper plant geometry with 4 m row length, 70 cm x 30 cm row to row and plant to plant spacing, respectively. Finally the plot size was 203 m² at each growing seasons. All agronomic and cultural practices were done manually and regularly during 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 middle rows 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 homogeneity of experimental error was examined by Bartlett's test. The analysis of variance (ANOVA) explained to part of the variations due to the effect of genotypes, years, environments and their interaction, also significant difference within these factors was estimated using LSD test at P = 0.05 and 0.01 probability level according to Gomez and Gomez, 1984.

1 The GGE-biplot was constructed based on the first two principal components (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 genotypes following formulas described by Yan *et al.*, 2000; Yan and Kang, 2003.

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

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6 Y_{ij} = mean response of i th genotype ($i = 1, \dots, I$) in the j th environment ($j = 1, \dots, J$).

7 μ = grand mean.

8 e_j = environment deviations from the grand mean.

9 λ_n = the Eigen value of PC analysis axis.

10 γ_{in} and δ_{jn} = genotype and environment PC scores for axis n .

11 N = number of PCs retained in the model.

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

13 GenStat version 17th 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) coordinates of average environment, (c) ranking the genotypes based on the ideal genotype, (d) ranking the environments based on the ideal environment, and (e) examining the relationship among the environments was used for graphical analysis.

20 **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

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RESULTS AND DISCUSSIONS

2 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 E for 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.

17 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 the genotypes have high variation around the overall mean. On average the genotypes revealed high 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.

27 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**.

5 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 (36.34%) 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.

21 In case of correlation between studied four yield traits (boll weight, seed cotton yield, lint yield and lint %) as shown in **Table 7**. The highly significant 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 a positive 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 environments during 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 2 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						

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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						

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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						

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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 (below diagonal)

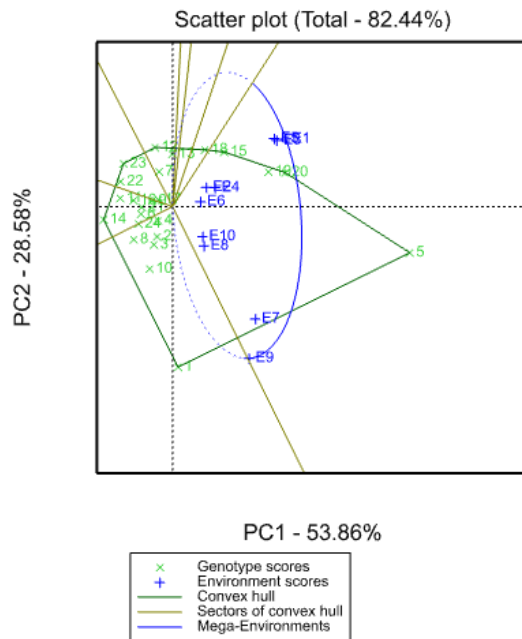
Traits	Boll weight g	Seed cotton yield g	Lint yield g	Lint %
Boll weight	1	-0.031	-0.037	-0.041
Seed cotton yield	-0.276	1	0.999**	-0.117
Lint yield	-0.247	0.994**	1	-0.074
Lint %	0.146	0.268	0.374	1

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 trials 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

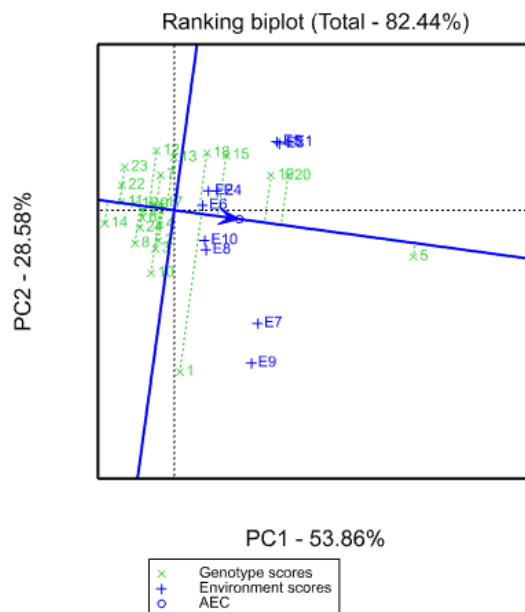
Abd El-Moghny and Max, 2015, Shaker et al., 2019 and Abdelmoghny et al., 2020. Figure 1 shows a polygon vertex connecting the genotypes G1, G5, G23, G12, G15 and G19, the furthest genotypes from the biplot point of origin were used to make the perpendicular. These genotypes have the longest vectors in 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 indicated less 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 genotype 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.



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Figure 1: Polygon view of the GGE-biplot for the which – one – where pattern for genotypes and 3 environments

Yield performance and stability of genotypes

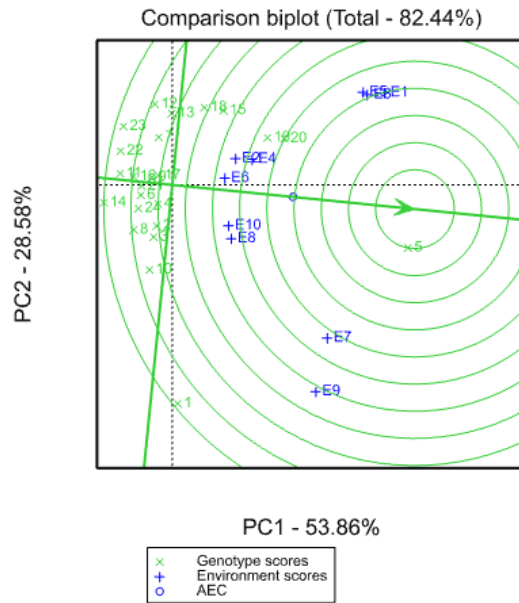
5 The genotypes were evaluated by the average environment coordination (AEC) method, the average environment is defined by the average PC1 and PC2 scores of all environments, which represented by the small circle as presented in **Figure 2**. The line was passing through this average environments and 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 at the left side which know as the lower yield genotypes and least stable.



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Figure 2: Average environment coordination (AEC) views of the GGE-biplot based on
 3 **genotype for ranking and stability of genotypes**

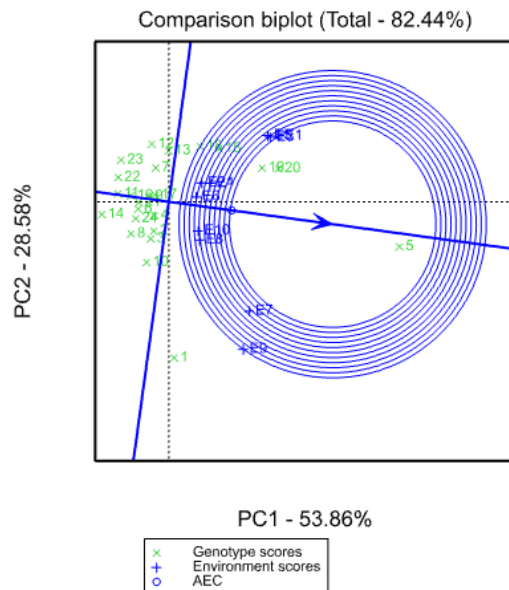
Ideal genotypes and ideal environment

5 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**.



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Figure 3: GGE-biplot with scaling focused on genotypes



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Figure 4: GGE-biplot with scaling focused on environments

1 CONCLUSION

2 The present study indicated that cotton lint yield was a good indicator to select the
3 highest genotypes under different environments. Experiments across different years, locations
4 will enable to identify the effect of the mega environments. The analysis of variance for the
5 lint cotton yield indicated that genotypes, environments, GE interaction was highly
6 significant. It showed that the GE interaction was an important source of cotton lint yield
7 variation and its biplot were the powerful for visualizing the response patterns of genotypes
8 and environments. The GGE-biplot method was concordant in discriminating environments
9 and genotypes for phenotypic stability. The genotypes G5, G19 and G20 achieved high lint
10 cotton yield and phenotypic stability in environments (E1, E3 and E5).

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UNDER PEER REVIEW