Journal of Sohag Agriscience (JSAS) 2024, 9(1): 153-163

ISSN 2735-5578
https://jsasj.journals.ekb.eg
JSAS 2024; 9(1): 153-163

Received: 01-06-2024
Accepted: 29-06-2024

Soliman A.M.
Rania M. Abdel-Tawab
S. R. N. Said
Cotton Research Institute
Agricultural Research Center
Giza
Egypt

Yasser A. M. Hefny
Agronomy Department
Faculty of Agriculture
Sohag University
Sohag
82524
Egypt

Corresponding author:
Yasser A. M. Hefny
yasser.hefny@agr.sohag.edu.eg

Evaluating the behavior of some Egyptian cotton genotypes under water stress conditions and its effect on yield and technological traits

Soliman A.M., Rania M. Abdel-Tawab, S. R. N. Said and Yasser A. M. Hefny

Abstract

An experiment was conducted during two successive summer seasons, 2022 and 2023 at Shandaweel Agric. Res. Station, A.R.C., Sohag, Egypt, to evaluate the behavior of 20 genotypes from Egyptian cotton to identify and isolate drought tolerant genotypes of Egyptian cotton under normal irrigation and drought stress conditions using nine drought tolerance indices. analysis of variance of the studied characters under the two environments (normal and drought) in the two years and their combined analysis showed that highly significant differences between genotypes in the separate and combined analysis. The effect of years showed highly significant differences between the two seasons for seed cotton / plant, lint yield / plant and fiber traits under the two conditions. The interaction of genotypes by years was significant for all traits except fiber length under normal irrigation, and for all traits under drought stress condition. Genotypes were caused in most of the variability rather than years and their interactions with genotypes. By the two methods, drought tolerance indices and mean performances we can screening drought tolerant genotypes which showed that the most drought tolerant genotypes which No. 6, 7, 11 and No.20 under Yp and Ys conditions. Also, drought tolerant genotypes cleared that the genotypes No.1, 6, 18 were the most drought tolerant genotypes for fiber traits. But, genotype (No.20) showed high seed cotton yield and fiber traits under Yp and Ys conditions and might be selected according to these indicators to upgrade drought tolerant trait in cotton. Thus, we can use these genotypes in breeding programs for improving drought tolerance crosses to overcome the water reduction and reduce the water consumption of the cotton crop. Then we can extend the reclame a large area of new lands that suffer from water deficiency. And use the new promising crosses for planting the new reclaim aria.

Keywords: Evaluation; correlation; Drought indices; G. barbadense.

INTRODUCTION

Cotton fiber is most important natural textile fiber in the world and Egyptian cotton (Gossypium barbadense L.,) is the most important cash crop in Egypt. Over 100 countries are sowing the cotton crop in the world; ensure income of about 250 million people (ICAC). Changing climatic condition is make a cultivation of cotton faces several challenges, which hinder crop growth, development and productivity.

Drought is the most critical a biotic stress having substantial impact on plant growth associated physiological process and cotton production is adversely affected by water stress. Insufficient soil water content during the sensitive growth stages such as blooming, flowering and fruit-setting stages can lead to a reduced in most traits. Also, drought has a wide range of effects on cotton, and related reports indicated that cotton affected by drought, resulting in a 34% reduction in cotton production (Ullah et al., 2017). Hence, breeding new varieties with high yield and strong drought resistance are the currently the main target (Cattivelli et al., 2008).

Likewise, it has become necessary to plant cotton in newly reclaimed soils and leaves the valley lands for other crops that cannot bear the lack of water. So, the new genotypes of cotton must be introduced to farmers in current scenario of climate change to the reports of UNO (Aslam et al., 2023). Malik et al., (2006) found that drought stress can reduce cotton productivity by affected many agronomic traits such as reduction in number of bolls/plants, size boll and plant height. Drought stress reduced yield, number of bolls, boll weight and induced earliness (Alishah and Ahmadikhah, 2009). Drought stress adversely affected yield, its components and fiber traits (Mahdi et al., 2014 and Hamoud et al., 2016). Mahdy et al. 2021, found that five tolerant indices which STI, MP, GMP, HM and DI Among ten tolerant indices could be considered a better tolerant index to detect drought tolerant genotypes. On the same way, Yehia (2020) found that, there are five tolerance indices i.e., MP, GMP, STI, YI and HM were considered as the best predictor of yield under drought stress and normal irrigation condition than the other indices. Likewise, fiber quality was significantly affected by drought levels (Gao et al., 2020). The MP, GMP and STI indices were positively and highly correlated with grain yield under normal and stress conditions. Therefore, STI, GMP and MP were able to identify tolerant and high yielding genotypes in both environments (Abdelghany et al. 2016).

The present study aims to evaluate twenty genotypes of Egyptian cotton under both normal irrigation and drought stress conditions to select the best genotype for tolerant water deficit stress, and test the efficiency of nine drought indices for distinguishing the drought-resistant genotypes under drought stressful environmental conditions.

MATERIALS AND METHODS

This study was carried out in the experiment farm of the department of cotton breeding at Sohag governorate, CRI, ARC, Shandaweel Research Station, Egypt. Twenty genotypes of Egyptian cotton (Table 1) were evaluated during two successive summer seasons of 2022 and 2023, under normal irrigation and water stress conditions to study effect of water stress (drought) on yield, yield components and fiber traits. The twenty genotypes were distributed in A randomized complete blocks design with three replications in the two seasons. The experiment unit consist of one row, row length was 4 meters long, 70 cm. apart and 40 cm. among hills. After emergence it was thinned to only one plant in hill. The usual cultural practices were followed throughout the growing seasons. Hence, the non-treated plants (control-normal), were irrigated (W1) is take nine irrigates/ season, as well as, the drought stress plants took six irrigates/ season (W2) in the first and the second seasons. Five random guarded plants were taken from each plot to determined yield, yield components and technology traits as follows: seed cotton yield/plant (S.C.Y./P. g), lint yield/plant (L.C.Y./P. g), lint percentage (L %), boll weight (B.W. g), seed index (S.I. g), micronaire reading (MR), fiber strength as pressley index (PI) and upper half mean length (UHM). All studied traits were calculated as the mean of the five plants from all replications in the two years. Significancy tests were calculated as outlined by Steel *et al.* 1997.

The analysis of variance and covariance was calculated as Miller *et al.* 1958. Correlation coefficients between drought indices were conducted using Pearson correlation coefficient (r).

Table 1. The origins of the all studied promising cotton genotypes.

Number	Genotype	Parents	Origin
1	H5 73/2018	H4 59/2017	[[(G.83 × (G.75 × 5844)] × G.90]] × G.91
2	H5 92/2018	H4 71/2017	[(G.83× (G.72×Dan.)]×CB58
3	H5 98/2018	H4 83/2017	G,80 × CB58
4	H5 113/2018	H4 92/2017	G.85 × CB58
5	H6 135/2018	H5 111/2017	[(G.83×(G.72×Dan.)]× Pima S 62 (24202)
6	H6 147/2018	H5 124/2017	
7	H6 152/2018	H5 134/2017	(G.91×G.90)× PimaS62(24202)
8	H7 159/2018	H6 138/2017	(G.91×G.90)× CB58
9	H8 180/2018	H7 165/2017	(G.90 × Aust.) × G.85
10	H8 192/2018	H7 181/2017	(G.90 × Aust.) × [G.83× (G.72 × Dan.)]
11	H8 196/2018		
12	H9 210/2018	H8 201/2017	(G.91×G.90)× G.85
13	H10 245/2018	H9 243/2017	(G.91×G.90)× Kara.
14	H11 247/2018	H10 262/2017	[(G.83 × G.80)× Dan.] × (G.90 × Aust.)
15	H11 248/2018		
16	H11 256/2018	H10 269/2017	(G.91×G.90)× G.80
17	H11 273/2018	H10 276/2017	
18	Families mixed		G.90 × CB58
19	Families mixed		[(G.83 × G.80)× G.89] × Aust.
20	Giza 95		[[(G.83 × (G.75 × 5844)] × G.80

Drought tolerance indices

Drought tolerance indicators based on studied traits for non-stress (Yp) and drought stress (Ys) conditions for each genotype were calculated using the formulas cited in (Table 2) to discriminate genotypes on the basis of drought response in terms for all studied traits.

Table 2. Drought tolerance indices used for the evaluation of cotton genotypes to drought conditions.

No.	Drought tolerance indices	Equation	Reference
1	Stress susceptibility index (SSI)	[1-(Ys/ Yp)] / [1-(Ȳs/ Ȳ	Fischer and Maurer, 1978
2	Tolerance index (TOL)	Yp– Ys	Rosielle and Hamblin, 1981
3	Mean productivity index (MP)	(Yp+Ys)/2	
4	Stress tolerance index (STI)	$(Yp \times Ys)/(\bar{Y}p)^2$	Fernandez, 1992
5	Geometric mean productivity (GMP)	$(Yp \times Ys)^{0.5}$	
6	Harmonic mean (HM)	[2(Yp×Ys)/(Yp+Ys)	Chakherchaman et al., 2009
7	Drought resistance Index (DI)	[Ys(Ys/Yp)]/ Ȳs	Lan, 1998
8	Yield stability index (YSI)	Ys / Yp	Bouslama and Schapaugh,
9	Stress susceptibility percentage index	[(Yp- Ys) / 2(Ȳp)] x100	Mosaavi et al.,2007

Yp and Ys: seed cotton yield of each genotype under non-stress and stress conditions, respectively.

RESULTS AND DISCUSSION

Analysis of variance

Analysis of variance for the studied traits under two environments (normal and stress) conditions in the two seasons and their combined (Tables 3 and 4), respectively, showed highly significant differences among genotypes in the separate and combined analysis. The effect of years showed highly significant differences between the two seasons for only two traits seed cotton yield and lint yield under two conditions. From these results we can understanding that the stability of yielding ability cotton traits differed from year to year. Furthermore, the interaction of genotypes by years was significant for all traits except for fiber length under normal irrigation, and for all traits under drought stress. Genotypes were caused in the most variability rather than years and their interactions with genotypes. These results agreed with those by Hamoud *et al.* (2016) and Mahdy *et al*. (2021) found significant differences between cotton genotypes in the separate and combined analysis.

The effect of years showed significant differences in most cases, and the interaction of genotypes by years was significant for all traits except few cases. Gao *et al.* (2020) found that fiber quality was significantly affected by drought level, Shilpa *et al.*, (2020) found that fiber fineness and bundle strength decrease in inferior direction as reduction of soil moisture levels.

Table 3. Mean squares of the all studied traits under normal irrigation in year1 and year2 with their combined analysis.

S.O.V	d.f	Seed cotton yield/ plant			Lint yield/ plant		
		Year 1	Year 2	Combined	Year 1	Year 2	Combined
Reps	2	0.076	4.98		0.365	0.71	
Year(y)	1			8602.13**			1411.11**
Reps/Years	4			2.87			0.54
Genotypes (G.)	19	2806.74**	478.54**	2741.6**	430.61**	78.55**	425.003**
G x Y	19			543.69**			84.16**
Error	38	8.69	5.056		2.41	1.48	
Error Com.	76			6.87			1.95
S.O.V	**d.f**	**Lint percentage**			**Boll weight**		
		Year 1	**Year 2**	**Combined**	**Year 1**	**Year 2**	**Combined**
Reps	2	0.06	0.17		0.037	0.011	
Year(y)	1			2.29			0.005
Reps/Years	4			0.117			0.024
Genotypes (G.)	19	5.49**	2.84**	4.34**	0.24**	0.22**	0.396**
G x Y	19			3.99**			0.064**
Error	38	0.37	0.29		0.01	0.01	
Error Com.	76			0.33			0.01
S.O.V	**d.f**	**Seed index**			**Pressley index**		
		Year 1	**Year 2**	**Combined**	**Year 1**	**Year 2**	**Combined**
Reps	2	0.023	0.068		0.001	0.006	
Year(y)	1			0.01			0.042
Reps/Years	4			0.046			0.003
Genotypes (G.)	19	0.25**	0.52**	0.441**	0.14**	0.098**	0.213**
G x Y	19			0.326**			0.03**
Error	38	0.05	0.02		0.01	0.008	
Error Com.	76			0.032			0.01
S.O.V	**d.f**	**Strength**			**Fiber length**		
		Year 1	**Year 2**	**Combined**	**Year 1**	**Year 2**	**Combined**
Reps	2	0.025	0.026		0.36	0.37	
Year(y)	1			1.44			10.68
Reps/Years	4			0.026			0.592
Genotypes(G.)	19	0.45**	0.394**	0.381**	1.84**	1.75**	2.29**
G x Y	19			0.464**			0.305
Error	38	0.012	0.007		0.052	0.043	
Error Com.	76			0.01			0.4

*, **, significant at 0.05 and 0.01 level of probability, respectively.

Table 4. Mean squares of the all studied traits under water stress condition in year1 and year2 with their combined analysis.

S.O.V	d.f	Seed cotton yield/ plant			Lint yield/ plant		
		Year 1	Year 2	Combined	Year 1	Year 2	Combined
Reps	2	1.67	1.94		0.45	0.052	
Year(y)	1			145.42**			11.72**
Reps/Years	4			1.81			0.14
Genotypes(G.)	19	868.7**	735.8**	1310.41**	118.36**	108.36**	186.79**
G x Y	19			294.08**			39.93**
Error	38	3.55	1.97		12.88	9.7	
Error Com.	76			2.76			0.297
S.O.V	d.f	Lint percentage			Boll weight		
		Year 1	Year 2	Combined	Year 1	Year 2	Combined
Reps	2	0.08	0.163		0.0007	0.0046	
Year(y)	1			4.01			0.021
Reps/Years	4			0.122			0.003**
Genotypes(G.)	19	7.75**	8.06**	8.71**	0.267**	0.329**	0.502**
G x Y	19			7.09**			0.094**
Error	38	0.37	0.67		0.0012	0.0008	
Error Com.	76			0.521			0.001
S.O.V	d.f	Seed index			Pressley index		
		Year 1	Year 2	Combined	Year 1	Year 2	Combined
Reps	2	0.016	0.0013		0.003	0.004	
Year(y)	1			0.44			0.018
Reps/Years	4			0.009			0.004
Genotypes(G.)	19	0.524**	0.676**	0.585**	0.17**	0.185**	0.268**
G x Y	19			0.616**			0.087**
Error	38	0.006	0.004		0.002	0.003	
Error Com.	76			0.005			0.003
S.O.V	d.f	Strength			Fiber length		
		Year 1	Year 2	Combined	Year 1	Year 2	Combined
Reps	2	0.046	0.005		0.035	0.009	
Year(y)	1			1.43			18.802
Reps/Years	4			0.025			0.022
Genotypes(G.)	19	0.927**	0.796**	0.71**	2.25**	1.74**	3.66**
G x Y	19			1.01**			0.329**
Error	38	0.008	0.007		0.02	0.019	
Error Com.	76			0.007			0.019

*, **, significant at 0.05 and 0.01 level of probability, respectively.

Mean performances under normal and drought conditions

Mean performances for all genotypes under two environments (normal irrigation and drought stress) conditions in the two years, their combined, and reduction% for all studied characters are shown in Table 5.

Yield traits

The results of mean performances for seed cotton yield/plant was ranged from 70.17g. (geno. No. 17) to 150.33g. (No. 6) and grand mean was 108.65 g., and from 46.48g. (No.1) to 101.90 g. (No.20) and grand mean was 80.96 g. at normal irrigation and drought stress condition, respectively, eight genotypes (No.3, 6, 7, 9, 10, 11, 16 and No. 20) were significantly exceeded the grand mean at normal irrigation, six genotypes from them were significantly exceeded the grand mean at drought stress condition. The reduction % in seed cotton yield traits ranged from 17.08% (No.12) to 40.53% (No.1) with an average of 25.05%. The mean performance for lint yield/plant was ranged from 27.67g. (geno. No. 17) to 59.52g. (No. 6) and grand mean was 42.60 g., and from 17.92g. (No.1) to 38.67 g. (No.20) and grand mean was 30.12 g. at normal irrigation and drought stress condition, respectively, eight genotypes (No.3, 6, 7, 9, 10, 11, 16 and No. 20) were significantly exceeded the grand mean at normal irrigation, the same genotypes except No.7 were significantly exceeded the grand mean at drought stress condition. The reduction % in lint yield traits ranged from 19.23% (No.19) to 43.75% (No.1) with an average of 28.92%. The results appeared that the reduction% in lint yield of drought stress was little more than in seed cotton yield, which indicating that lint was more affected than seeds by drought stress. only two genotypes (No.1 and No. 2) were significantly surpassed the grand mean in lint percentage at normal irrigation, while five genotypes (No.1, 2, 7, 10 and No.14) were significantly surpassed the grand mean in lint percentage at drought stress condition, Lint percentage was slightly affected due to that drought stress affected both of lint and seeds. Most of genotypes were surpassed the grand mean in boll weight and seed index at both normal and drought stress condition. Mahdi *et al.* (2014) found that reduction % in seed cotton yield/plant by drought stress was reached to (%47.03) and added that it was probably due to a decrease of bolls/plant. Water stress caused a reduction of 37% in seed cotton yield/plant, 27% in number of bolls/ plants, 14% in boll weight and 14% in days to first flower (Bakhsh *et al.*, 2019).

Table5. Mean performance and reduction (RD%) of all studied traits under two environments (normal and drought) over the two seasons in cotton genotypes.

Geno.	Seed cotton yield			Lint yield			Lint percentage			Boll weight		
	N	D	Red%	N	D	Red%	N	D	Red%	N	D	Red%
1	78.17	46.48	40.53	31.85	17.92	43.75	40.68	38.67	4.96	3.17	2.52	20.66
2	110.20	89.73	18.57	44.88	34.65	22.80	40.64	38.60	5.01	3.30	2.73	17.29
3	129.98	99.68	23.31	51.40	36.58	28.83	39.43	36.69	6.93	3.02	2.31	23.59
4	103.73	72.75	29.87	39.00	26.15	32.95	37.70	36.01	4.49	2.96	2.39	19.33
5	78.57	63.02	19.79	30.97	23.85	22.98	39.47	37.81	4.20	3.01	2.26	24.90
6	150.33	101.00	32.82	59.52	36.57	38.56	39.49	36.24	8.22	3.09	2.39	22.73
7	133.32	81.07	39.19	51.35	31.02	39.60	38.38	38.48	0.25	3.45	2.64	23.61
8	106.08	78.18	26.30	41.73	28.77	31.07	39.36	36.90	6.25	3.08	2.28	26.01
9	121.62	91.97	24.38	47.08	32.95	30.02	38.75	35.73	7.80	3.06	2.29	25.27
10	116.50	80.70	30.73	45.40	31.23	31.20	39.03	38.67	0.93	2.46	1.77	27.83
11	140.87	89.38	36.55	55.75	33.85	39.28	39.75	37.99	4.43	2.55	1.79	29.84
12	89.78	74.45	17.08	35.80	27.35	23.60	39.86	36.57	8.26	3.11	2.52	18.94
13	99.63	78.37	21.34	39.33	29.15	25.89	39.47	37.27	5.57	3.20	2.59	19.21
14	101.78	80.53	20.88	40.65	31.13	23.41	39.90	38.66	3.10	2.58	1.86	27.86
15	92.32	75.40	18.32	35.15	27.57	21.57	38.05	36.57	3.89	3.33	2.71	18.69
16	115.77	90.67	21.68	46.23	34.48	25.41	39.94	38.06	4.72	3.19	2.67	16.17
17	70.17	51.93	25.99	27.67	18.63	32.65	39.49	35.96	8.94	2.95	2.08	29.53
18	97.62	81.70	16.31	36.83	28.12	23.67	37.75	34.37	8.95	2.90	2.22	23.20
19	109.47	90.27	17.54	41.87	33.82	19.23	38.37	37.62	1.94	3.14	2.49	20.89
20	127.10	101.90	19.83	49.58	38.67	22.02	38.98	37.89	2.79	3.17	2.42	23.90
Mean	108.65	80.96	25.05	42.60	30.12	28.92	39.23	37.24	5.06	3.03	2.34	22.97
LSD0.05	4.48	2.84		2.39	0.93		0.98	1.23		0.17	0.05	
LSD0.01	6.12	3.88		3.26	1.27		1.34	1.68		0.23	0.07	

Con. Table 5.

Geno.	Seed index			Fiber length			Micronaire reading			Pressley index		
	N	D	Red%	N	D	Red%	N	D	Red%	N	D	Red%
1	10.33	8.45	18.18	29.32	27.50	6.20	4.10	3.39	17.34	10.26	9.36	8.80
2	10.22	8.30	18.75	30.87	29.25	5.24	3.81	2.71	28.92	9.73	8.46	12.97
3	9.88	7.97	19.38	29.77	27.47	7.73	4.03	3.15	21.75	9.91	8.64	12.75
4	10.05	8.09	19.51	31.05	29.22	5.90	4.16	3.19	23.34	10.08	9.04	10.31
5	9.62	7.92	17.72	30.92	29.50	4.58	4.27	3.13	26.76	9.59	8.31	13.30
6	10.56	8.74	17.21	30.92	29.63	4.15	4.16	3.18	23.59	9.83	8.67	11.85
7	10.13	8.17	19.31	29.85	27.98	6.24	4.10	3.11	24.26	9.68	8.40	13.24
8	9.81	7.58	22.68	30.07	28.13	6.43	4.14	3.14	24.10	9.88	8.64	12.61
9	10.16	8.23	19.04	30.95	29.35	5.17	3.72	2.68	28.09	10.01	8.81	12.00
10	10.29	8.24	20.00	30.75	28.85	6.18	4.21	3.29	21.99	10.31	9.22	10.59
11	9.92	7.92	20.14	30.43	28.59	6.05	4.06	3.07	24.47	10.06	8.71	13.44
12	9.73	7.79	19.90	29.58	27.77	6.14	4.14	3.25	21.32	10.00	8.99	10.08
13	9.87	7.72	21.85	30.47	28.27	7.22	4.15	3.04	26.78	9.53	8.35	12.45
14	9.82	7.95	19.01	29.85	27.88	6.59	4.02	3.21	20.12	9.75	8.57	12.12
15	9.92	8.03	19.04	29.62	27.73	6.36	4.18	2.99	28.54	10.01	8.66	13.55
16	10.40	8.54	17.84	30.62	28.70	6.26	4.42	3.51	20.57	10.07	8.72	13.44
17	10.38	8.54	17.68	29.95	27.53	8.07	4.25	3.37	20.53	10.32	9.22	10.68
18	10.06	8.52	15.26	31.30	29.07	7.14	4.49	3.48	22.45	10.37	9.31	10.16
19	9.72	7.96	18.12	31.12	29.38	5.57	4.40	3.20	27.29	10.25	9.23	9.90
20	9.68	7.89	18.49	31.10	29.57	4.93	4.27	3.13	19.16	10.23	9.22	9.83
Mean	10.03	8.13	18.96	30.58	29.07	4.96	4.14	3.16	23.57	9.99	8.83	11.70
LSD0.05	0.31	0.12		1.08	0.24		0.17	0.09		0.17	0.14	
LSD0.01	0.42	0.17		1.48	0.32		0.23	0.13		0.23	0.20	

Fiber traits

Looking for the fiber traits, the mean performance of the most genotypes under study were exceeded the grand mean in both irrigation treatments, and affected by drought stress. There was significant effect among genotypes for fiber traits under both environments. Fiber length was 30.95 mm (N) - 29.25 mm (D) 4.15 mm Red**%**. In terms of fiber length, No. 6 showed the best performance under both environments. Fiber fineness (Micronaire reading) was 4.10 (N) – 3.39 (D) 17.34 Red**%**, No. 1 had lower micronaire reading than the check (table 6). Fiber strength (Pressley index) was 10.26 g/tex (N) - 9.36 g/tex (D) 8.80 Red**%**, No. 1 had better than check genotypes. While No. 20 was the better genotypes for all fiber traits, the previous results confirm the significant differences showed between genotypes. The effect of the environment on cotton traits were studied from many authors. Significant differences were observed between varieties for fiber traits (Rahman *et al.,* 2000). Fiber traits was significantly affected by drought stress and probably due to a decrease of fiber traits (Centin and Oktay, 2008).

Drought Tolerance indices

Table 6 was contained a values of nine drought tolerance indices i.e., Tolerance index (TOL), Stress susceptibility index (SSI), Mean productivity index (MP), Stress tolerance index (STI), Harmonic mean (HM), Geometric mean productivity (GMP), Drought resistance Index (DI), Yield stability index (YSI) and Stress susceptibility percentage index (SSPI) which calculated based on the combined mean of seed cotton yield/plant for 20 cotton genotypes under two environments (normal irrigation (Yp) and water stress conditions (Ys)). Results of seed cotton yield/plant under drought tolerance condition (Ys) for all genotypes were affected and decreasing value of 25.49% than under normal irrigation condition (Yp) over the two seasons. Lower SSI, TOL and SSPI values as well as higher MP, GMP, STI, YSI, DI and HARM values were recorded by the genotypes would be more tolerant. Selection depend on a combination of indicators may give a more useful criterion for improving drought resistance of cotton. Five genotypes which No.5, 12, 15, 18 and No.19 were accounted the highest values by YSI and the lowest values by SSI, TOL and SSPI, these results showed that the previous genotypes were considered as the most droughts tolerant genotypes and desirable under Ys. furthermore, a value by SSI, TOL and SSPI were the highest as well as the lowest values by YSI were found for the genotypes No.6, No.7, No.11 and No.20. According to the previous results, genotype (No.20) showed high SCY/P under two environments conditions and might be selected according to these indicators to improve drought tolerant in cotton.

Table 6. Comparison of drought tolerance indices under normal (Yp) and drought stress (Ys) conditions for the 20 cotton genotypes.

Geno.	Drought indices									
	Yp	**Ys**	**SSI**	**TOL**	**MP**	**STI**	**GMP**	**HM**	**DI**	**YSI**	**SSPI**
1	78.17	46.48	1.59	31.68	62.33	0.31	60.28	58.30	0.34	0.59	14.58
2	110.20	89.73	0.73	20.47	99.97	0.84	99.44	98.92	0.90	0.81	9.42
3	129.98	99.68	0.91	30.30	114.83	1.10	113.83	112.83	0.94	0.77	13.94
4	103.73	72.75	1.17	30.98	88.24	0.64	86.87	85.52	0.63	0.70	14.26
5	78.57	63.02	0.78	15.55	70.79	0.42	70.36	69.94	0.62	0.80	7.16
6	150.33	101.00	1.29	49.33	125.67	1.29	123.22	120.82	0.84	0.67	22.70
7	133.32	81.07	1.54	52.25	107.19	0.92	103.96	100.82	0.61	0.61	24.05
8	106.08	78.18	1.03	27.90	92.13	0.70	91.07	90.02	0.71	0.74	12.84
9	121.62	91.97	0.96	29.65	106.79	0.95	105.76	104.73	0.86	0.76	13.64
10	116.50	80.70	1.21	35.80	98.60	0.80	96.96	95.35	0.69	0.69	16.47
11	140.87	89.38	1.43	51.48	115.13	1.07	112.21	109.37	0.70	0.63	23.69
12	89.78	74.45	0.67	15.33	82.12	0.57	81.76	81.40	0.76	0.83	7.06
13	99.63	78.37	0.84	21.27	89.00	0.66	88.36	87.73	0.76	0.79	9.79
14	101.78	80.53	0.82	21.25	91.16	0.69	90.54	89.92	0.79	0.79	9.78
15	92.32	75.40	0.72	16.92	83.86	0.59	83.43	83.01	0.76	0.82	7.78
16	115.77	90.67	0.85	25.10	103.22	0.89	102.45	101.69	0.88	0.78	11.55
17	70.17	51.93	1.02	18.23	61.05	0.31	60.37	59.69	0.47	0.74	8.39
18	97.62	81.70	0.64	15.92	89.66	0.68	89.30	88.95	0.84	0.84	7.32
19	109.47	90.27	0.69	19.20	99.87	0.84	99.40	98.94	0.92	0.82	8.84
20	127.10	101.90	0.78	25.20	114.50	1.10	113.80	113.11	1.01	0.80	11.60

Genotypes with low SSI values were considered as stress tolerant, because such genotypes showed a lower reduction in seed cotton yield under stress environment compared to non-stress environment. Many researchers were used SSI to identify resistant and sensitive genotypes (Winter *et al.*, 1998). indicated that a values by SSI >1 indicates above-average susceptibility while a values by SSI <1 indicates below-average susceptibility to drought stress (Gutteri *et al.*, 2001). In respect to current study, the lowest value of SSI belonged to genotypes No.18, 12, 19, 15 and No.2, were more tolerant than No.1, 7 and No.11 and appeared to be a suitable selection index to distinguish tolerance genotypes. However, SSI was evaluated based on yield ratio of each genotype in stressed conditions to non-stressed conditions as compared with the proportion in the total genotypes. Thus, two cultivars with high yield or low in both conditions can have the same amount of SSI, so selection process based on this index lead reformer to make a mistake (Naeimi et al., 2008). Regarding to GMP, MP, HM and STI indicators, four genotypes which No.6, 7, 11 and No.20 have the highest values of SCY/P with high yield stability under the two environments conditions can considered as drought tolerance genotypes, thus, the selection should be depended on high rate of these drought tolerance indices. On the contrary, two genotypes which No.1 and No.17 with the low values of these indices andconsidered as susceptible genotypes. By these indices, the other genotypes were identified as semi-tolerant to drought stress. Similar results for the genotypes were found between MP, GMP, STI and HM indices and SSI, TOL and SSPI and YSI indices, which suggests that these indicators are equal for selecting genotypes that highly yielding under the two environments conditions, and it seems that these indices had succeeded in selection genotypes with high yield under Yp and Ys conditions. Yehia (2020) noted that MP, GMP, STI, YI (yield index) and HM were the best indices to detect drought tolerance genotypes when studied the ability of 13 drought tolerance indices in 24 cottons (*G. barbadense* L.).

Correlation analysis

Phenotypic correlation among drought tolerance indices under normal and stress drought condition are shown in Table 7. High positive correlation was observed between Yp and Ys (r = 0.85) which means that high yielding genotypes can be selected based on them under both stress and non-stress conditions. Similar results were obtained by Yehia (2020). Farshadfar and Sutka (2002) stated that if correlation coefficient between Yp and Ys is between 0 and 0.5 under experimental condition and genetic variance ratio is less than one genotypic selection for yield might increase mean grain yield under non-stress condition. In the other hand, results showed that high positive correlations between Yp and all drought tolerance indices except for DI was moderate and SSI was low and negative with YSI. While, Ys was highly positively correlated with MP, GMP, DI, HARM and STI, these indicate that genotypes with higher for these indices STI are superior under stress conditions. Our results are in agreement with those reported by Abdelghany et al. (2016) in wheat, Fernandez (1992) in bean and Reynolds et al. (2007) in wheat where their studies indicated the effectiveness of selection criteria for assessing plant drought tolerance and reported that STI, MP and GMP are more suitable to screen tolerance because they had high positive correlation with grain yield under both stress and non- stress conditions. Results in Table 7 revealed that negative correlations between Ys and SSI (r=-0.22) which means selection based on this index results in yield loss under stress conditions. Hence, it is not suitable indices for screening drought tolerant genotypes. Also, correlation analysis indicated that seed cotton yield under both stress (Ys) and non-stress conditions (Yp) were highly positively correlated with STI, GMP and MP. Therefore, these indices are more appropriate in screening high- yielding cotton genotypes than those of SSI and TOL, these results are in agreement with Yehia (2020).

Table 7. Correlation coefficients between drought tolerance indices over the two seasons

Variable	Ys	SSI	TOL	MP	STI	GMP	HM	DI	YSI	SSPI
Yp	0.85**	0.31	0.75**	0.98**	0.97**	0.96**	0.95**	0.54*	-0.31	0.75**
Ys		-0.22	0.29	0.95**	0.94**	0.96**	0.97**	0.90**	0.22	0.29
SSI			0.85**	0.10	0.10	0.05	0.004	-0.62**	-1.0**	0.85**
TOL				0.59**	0.58**	0.55*	0.51*	-0.155	-0.85**	1.00**
MP					0.99**	0.99**	0.99**	0.71**	-0.096	0.59**
STI						0.99**	0.99**	0.71**	-0.10	0.58**
GMP							1.0**	0.74**	-0.05	0.55*
HM								0.77**	-0.004	0.51*
DI									0.62**	-0.16
YSI										-0.85**

The high correlation between STI and GMP (r = 0.99) due to STI is calculated based on GMP. Therefore, high values of STI detect high-yielding drought tolerant cotton genotypes. Similar results were obtained by Abdelghany et al. (2016). It can be concluded that yields under both stress and non-stress conditions were dependent. Furthermore, STI, GMP and MP were able to identify genotypes with high yielding in both environments. Even though selection indices depend mainly on the stress severity which supports the idea that only under moderate stress conditions, potential yield greatly influences yield under stress condition where MP, STI and GMP were better predictors than TOL and SSI for Yp and Ys. Yehia (2020) noted that MP, GMP, STI, YI (yield index) and HM were the best indices to isolate drought tolerance genotypes when studied the ability of 13 drought tolerance indicators in 24 cottons (*G. barbadense* L.). Mahdy *et al.* (2021) found that five tolerant indices i.e., STI, MP, GMP, HM and DI could be considered the best tolerant indices to isolate both of susceptible and tolerant cotton genotypes.

CONCLUSION

The nine drought tolerance indices under study showed that, five indices which MP, GMP, STI, YI and HARM, under normal and stress conditions, and the other drought tolerance indices under stress condition were the best for recognition drought tolerant genotypes. During screening drought tolerant genotypes using mean performances and drought tolerance indices, the genotypes No.6, 7, 11 and No.20 were the most drought tolerant genotypes, genotype (No.20) showed high seed cotton yield under Yp and Ys conditions and might be selected according to these indices to improve drought tolerance in cotton. Therefore, it is recommended to be used in breeding program for improvement of drought tolerance Egyptian cotton.

REFERENCES

Abdelghany, A.M., Hanaa M. Abouzied and M.S. Badran (2016). Evaluation of some Egyptian wheat cultivars under water stress condition in the north western coast of Egypt. J.Agric.&Env.Sci.Dam.Univ.,Egypt .,15 (1):63-84.

Alishah, O. and A. Ahmadikhah (2009). The effects of drought stress on improved cotton varieties in Golesatn Province of Iran. *International J. Plant Prod.*, 3(1).: 17-26.

Aslam, S., S.B. Hussain, M. Baber, S. Shaheen, S. Aslam, R. Waheed, H. Soe and M.T. Azhar (2023). Estimation of drought tolerance indices in upland cotton under water deficit conditions. Agronomy J. 13(4):984.

Bakhsh, A., M. Rehman, S. Salman and R. Ullah (2019). Evaluation of cotton genotypes for seed cotton yield and fiber quality traits under water stress and non- stress conditions' *Sarhad J. of Agric*., 35(1) : 161-170.

Bouslama, M. and W.T. Schapaugh (1984). Stress tolerance in soybean. Part 1: Evaluation of three screening techniquesfor heat and drought tolerance' *Crop Science*, 24, : 933-937.

Cattevelli, L., F. Rizza, F.W. Badeck, E. Mazzucotelli, A.M. Mastrangelo and E. Francia (2008). Drought tolerance improvement in crop plant: an integrated view from breeding to genomics. Field Crops Res. 105:1-14.

Cetin K. and G. Oktay (2008). Yield and Technological Characteristics in Advanced Cotton (*Gossypium hirsutum L*.) Lines Under Drougth Stress Plant Breed. 119:11-27.

Chakherchaman, S.A., H. Mostafaei, L. Imanparast and M.R. Evasion (2009). Evaluation of drought tolerance in lentil advanced genotypes in Ardabil region' *Iran J. Food Agric. Env.*, 7(3-4):283-288.

Farshadfar, E. and J. Sutka (2002). Multivariate analysis of drought tolerance in wheat substitution lines. Cereal Res. Commu., 31: 33-39.

Fernandez, G.C.J. (1992). Effective selection criteria for assessing plant stress tolerance' In: *Proceeding of the*

Fischer, R.A. and R. Maurer (1978). Drought resistance in spring wheat cultivars. I. Grain responses' *Australian Journal of Crop Sci.*, 29, pp, 897-912.

Gao, M., J.L. Snider, H. Bai, W. Hu, R. Wang, Y. Meng, Y. Wang, B. Chen and Z. Zhou (2020). Drought effects on cotton (*Gossypium hirsutum* L.) fiber quality and fiber sucrose metabolism during the flowering and boll-formation period' one line https://doi.org/10.1111/jac.12389] .

Guttieri, M. J., J. C. Stark, K. Brien and E. Souza (2001). Relative sensitivity of spring wheat grain yield and quality parameters to moisture deficit. Crop Sci., 41, 327-335.

Hamoud, H.M., A. Soliman, M.S.M. Eldemery and K. F. Abdellatif (2016). Field performance and gene expression of drought stress tolerance in cotton (*Gossypium barbadense* L.)' *Biotechnology J.International*, 14(2), pp, 1-9.

Rahman S., M.S. Shaheen, M. Rahman and T.A. Malik (2000). Evaluation of excised leaf water loss and relative water content as screening techniques for breeding drought resistant wheat. Pak. J. Biol.Sci., 3: 663-665.

Lan, J. (1998). Comparison of evaluating methods for agronomic drought resistance in crops' *Acta Agriculturae Boreali-Occidentalis Sinica*, 7, pp, 85- 87.

Mahdi, Z., Gh. R. Mohammadifard, F. Bazrafshan and M. Zadehbagheri (2014). Evaluation of cotton (*Gossypium hirsutum* L.) genotypes to drought stress' *Inter.l J. Biosc.*, 4 (12), pp, 158 –166.

Mahdy E.E., S.F. Abou-Elwafa., G.H. Abd El-Zaher and N.I. Abd El-Rahman (2021). Drought tolerance indices and path-analysis in long staple cotton genotypes (*G. barbadense*). SVU-International Journal of Agricultural Sciences, 3 (3): 177-191.

Malik, T.A., Sanaullah and Malik, S. (2006). Genetic linkage studies of drought tolerant and agronomic traits in cotton' *Pak. J. Bot.*, 38(5):1613-1619.

Miller, P.A., J.C.Jr. Williams, H.F. Robinson and R.E. Comstock (1958). Estimates of genotypic and environmental variances and covariances in Upland cotton and their implication in selection. *Agron. J.*, 50:126-131.

Moosavi S.S; B. Yazdi MR, Samadi, AA, Naghavi; H, Dashti; and A. Pourshahbazi (2007). Introduction of new indices to identify relative drought tolerance and resistance in wheat genotypes. Desert. 12(2):165-178.

Naeimi, M., G. A. Akbari, A. H. Shirani, S. A. M. M. Sanavi, S. A. S. Noori and H. jabari(2008). Evaluation drought tolerance in different varieties by evaluation indices of stress in end of growth season. j. Prod. Agri. plants 1:83-89.

Reynolds, M., B. Skovmand, R. Trethowan and W. Pfeiffer (2007). Evaluating conceptual model for drought tolerance, CIMMYT.Mexico.

Rosielle, A.A. and J. Hamblin (1981) 'Theoretical aspects of selection for yield in stress and nonstress environments' *Crop Sci*., 21, pp, 943-946.

Shilpa, B., P. Pusadkar and C.N. Chandrasekhar (2020). Assessment of fiber qualityand yield allied parameters underdrought condition in Cotton. *Int. J. Curr. Microbiol*. Sci., 9(4):1237- 1244.

Steel, R.G.D., J.H. Torrie and D.A. Dicky (1997). Principles and Procedures of Statistics. A Biometrical Approach. 2nd Ed. McGraw Hill Book Company. Inc. New York, NY.

Ullah, A., H. Sun, X. Yang and X. Zhang (2017). Drought coping strategies in cotton: increased crop per drop. Plant Biotech. J. 15:271-284.

Winter, S. R., J. T. Musick and K. B. Porter (1998). Evaluation of Screening Techniques for Breeding Drought-Resistant Winter Wheat. Crop Sci., 28:512-516.

Yehia, W.M.B. (2020). Evaluation of same Egyptian cotton (*Gossypium barabadense* L.) Genotype to water stress by using drought tolerance indices. *Elixir Agriculture*, 143, pp, 54133-54141.