SVU-International Journal of Agricultural Sciences
Volume 3 Issue (4) pp.: 105-118, 2021
Print ISSN 2636-3801 | Online ISSN 2636-381X
Doi: 10.21608/SVUIJAS.2021.94700.1140

RESEARCH ARTICLE

Salinity indices and path analysis in Egyptian long-staple cotton cultivars

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Abstract

Soil salinity is one of the serious abiotic stresses adversely affects crop production. The objectives of this study were to screen fifteen long-staple cotton belong to Gossypium barbadense L. for salinity tolerance, salinity indices, genotypic correlations, and path-coefficient analysis. Under normal soil the genotypes differed significantly in most traits in both years. Under saline soil the differences among genotypes re significant in one year and in the combined analysis for SCY/P, LY/P, SI, NS/B, PH, and Pressley index. The cultivars "G 90 x Aus", G95, G 90, G 80, and G 83 showed the highest performance in SCY/P, LY/P, Lint%, NB/P and NS/B either under normal or saline soil. The reduction% caused by salinity was observed for PH (55.92%), LY/P (52.21%), SCY/P (48 75%), NB/P (32.47%), LI (5.68%), Micronaire reading (11.22%), Pressley index (6.63%) and UHM length (0.89%). Giz90 x Aus followed by Giza 90 showed the best tolerance to salinity stress. The STI, MP, GMP, HM and DI detected both of tolerant and susceptible genotypes and could be considered the best tolerant indices. The direct and indirect effects of SCY/P components varied greatly under both environments. The direct effects of the SCY/P components under normal soil were 0.504, 0.401, 0.153 and 0.147 for NB/P, LY/P, SI, and NS/B, respectively. However, under saline soil the direct effects were 0.802, 0.178, 0.128 and 0.050 for LY/P, NB/P, NS/B and SI, respectively. Therefore, under both environments, selection should be paid mainly on NB/P and LY/P.

Keywords: *G. barbadense;* evaluation; Salinity tolerance; Correlation; Path-analysis.

1. Introduction

The possibility of exploiting saline lands becomes a vital aspect in agricultural development. The abiotic stress, drought along with salinity is expected to cause up to 50% of arable land loss worldwide(Buchanan, 2000; Bartels and Sunkar, 2005; Mittler, 2006; Abdelraheem *et al.*, 2019)**,** disturb plant growth, resulting in the overproduction of reactive oxygen species, which are extremely reactive and toxic (Mohamed *et al.*, 2018). Salinity reduced transpiration, stomatal conductance, and the growth of plants. High Ca^{2+} level and salinity decreased Potassium uptake, affect yield and decreased maturity of the individual fibers (Leidi *et al*., 1991; Razzouk and Whittington, 1991). At salinity affected soil, various yield components varied significantly among the varieties tested in the field (Anjum *et al.*, 2005). Abdelraheem *et al.* (2018) reported that drought under the field conditions and salt stress in the greenhouse reduced cotton plant growth at the seedling stage, and decreased lint yield and fiber quality traits in the field. Up till now, the genetic engineering did not produce salt tolerance variety (Sheikholeslami *et al.*, 2018)**.** Under salinity, behavioral pattern was not same at all stages of cotton (Manikandan *et al.*, 2019). Drought and salinity stresses, alone or in combined, caused significant reduction in plant

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Received: September 7, 2021; Accepted: September 29, 2021; Published online: October 13, 2021

growth, chlorophyll content and photosynthesis in two cotton genotypes, with the largest impact visible under combined stress (Mohamed *et al*., 2018) and reduction in yield was caused by reduction in the number of bolls and can cause early maturing cotton (Razaji *et al.*, 2020)**.**

(Ibrahim *et al.*, 2019) found that adaptability estimates indicated that the promising strains for different traits were unstable for seed cotton and lint yields. (Ullah *et al.*, 2015) evaluated nine cotton cultivars and indicated significant ($P \leq 0.01$) differences for the investigated parameters. Furthermore, significant differences among Egyptian cotton genotypes, environment, and interaction for all characters except for cotton yield were noted (Ali *et al.*, 2014). The effects of the growing season, interactions between genotype x season, location x season, genotype x location and the second- order interaction were significant for most studied characters of Egyptian cotton except for fiber strength (El-Seidy *et al.*, 2017; Shaker, 2017; Shaker *et al*., 2019).

The boll weight followed by the number of bolls per plant, and the number of sympodia per plant were positively correlated with seed cotton yield per plant in the F_2-populations (Joshi and Patil, 2018). The simple linear correlation and path coefficient analysis showed that seed cotton yield was highly significantly and positively correlated with most traits(Ahmed *et al.*, 2019; Chapepa *et al.*, 2020). The boll weight and number of bolls per plant had highest direct effect on seed cotton yield per plant, whereas traits like plant height, UHML, fiber strength and lint index had direct negative effect on yield (PG *et al*., 2018), and fiber elongation, fiber strength, and fiber fineness have direct positive effects on seed cotton yield (Queiroz *et al.*, 2019). In Egyptian cotton earliness index and production rate index had the maximum contribution in seed cotton yield per plant, therefore, may be used as useful criteria to increase yield (Mahdi and Emam, 2020). The objectives of this study were to 1) screen several cotton obsolete and cultivated cultivars belong to *Gossypium barbadense* L. for salt tolerance, 2) study the ability of ten selection indices to identify salt-resistant cultivars under normal and saline soils conditions, 3) study correlations and path-coefficient analysis among seed cotton yield and its components.

2. Materials and Methods

2.1. Plant materials

The present study was carried out at Al-ghoraizat village, Maragha city, (salinity soil) and Izbat Al-Hama, Tema city, Sohag governorate during the two summer seasons of 2018 and 2019. The basic materials were fifteen divergent Egyptian cotton varieties belong to *G. barbadense*, L. These varieties are shown in Table 1. The pure seeds of these varieties were obtained from Cotton Res. Ins., Agric. Res. Center, Giza, Egypt. The name, pedigree and the main characteristics of these varieties are presented in Table 1.

In both seasons of 2018 and 2019, the fifteen genotypes shown in Table 1 were sown on the 28^{th} and 29^{th} March under salinity and normal soil, respectively. A randomized complete blocks design with three replications was used. The plot size was two rows, four-meter-long, 60 cm apart and 40 cm between hills within a row. After full emergence, seedlings were thinned to one plant per hill. All the routine agricultural practices and plant protection were adopted in all the plots uniformly throughout the growing season.

The recorded characters on 10 guarded plants were seed cotton yield/plant (SCY/P, g), lint yield/plant (LY/P, g), Lint%, number of bolls/plant (NB/P), boll weight (BW, g) (estimated from the weight of 25 sound bolls taken randomly from each plot before the first pic), seed index (SI, g), lint index (LI, g), number of seeds /bolls (NS/B) (estimated as boll weight (100- lint %) / seed index), plant height

(PH, cm), days to first flower (DFF) (was measured as the days from sowing to the appearance of the first flower on five plants in each plot), fiber fineness, was expressed as Micronaire reading (Mic), fiber length, the UHM length was measured by H.V.I. and fiber strength as Pressley Index (strength) was measured by the H.V.I instrument.

Table 1. The name, characteristics and pedigree of the varieties

Genotypes	Pedigree	Characteristics
A-Giza 95	[(G.83 × (G.75 × 5844)) × G.80]	A new long- staple cotton variety, characterized by high yielding ability, high lint percentage, early maturity, and heat tolerance (cultivated).
B-Giza 90	G.83 × Dandara	Long- staple variety for upper Egypt, high yield, and lint percentage (cultivated).
C-Giza 90 × Aus	G.90 × Australian	Characterized by high yielding and earliness (obsolete).
D-Giza 80	G. 66 × G. 73	Long-staple variety, high in yield and lint percentage (obsolete).
E-Giza 83	G.67 x G.72	The long-staple variety. it is characterized by high linty percentage and yield.
F-Giza 85	G.67 x C.B. 58	A long-staple variety, characterized by high yield and earliness variety (obsolete).
G-(Giza 90 × Aus) × G. 85	(Giza90 × Aus) × G.85	A long-staple variety, characterized by high yield and earliness variety.
H-Ashmouni	G1	Long-stable variety (obsolete).
I-Dandara	Selected from Giza-3	Long-stable variety(obsolete).
J-(G.91 × G.90 × G.80)	(G.91 × G.90 × G.80)	Promising line in the 12 generation.
K-(Giza 90 × Aus) × (G.83 × G.80 × Dandara)	(G. 90 × Aus) × (G.83 × G. 80 × Dandara)	Promising line in the14 generation.
L-(Giza 90 × Aus) × (G.83 × G.72 × Dandara)	(G. 90 × Aus) × (G.83 × G.72 × Dandara)	Promising line in the13 generation.
M-Krashinki	Russian	Characterized by high yielding earliness and good fiber traits.
N-(Giza 90 × Aus) × (G.83 × G.72 × Dandara)	(G. 90 × Aus) × (G.83 × G.72 × Dandara)	Promising line in the13 generation.
O-Australian	G=Giza	characterized by high early maturity and high boll number.

2.2 Soil analysis

Table 2 represented some soil properties. The soil texture was silty clay loam (normal soil). Furthermore, the results explained that the soil was under a medium saline soil class (saline soil); however, the soil was not alkaline according to Na+, Ca+2, and Mg+2 concentrations, where the sodium adsorption ratio was 11.03. In addition, the changes in EC values were insignificant during the two seasons. Likewise, OM content was in the same range through the two seasons. In the same manner, N, P, K contents in the soil were the same during the two seasons. On the other hand, soils containing high concentrations of soluble salts will interfere with the normal growth and development of the crops where plants are grown in this soil often seem drought stressed even when adequate water is available because the osmotic potential of the soil prevents the roots from water uptake. As well as the availability of the nutrients N, P, and K were affected by soil salinity.

2.3. Statistical analysis

The analysis of variance, mean separation, and covariance were performed in plot mean basis follow a randomized complete blocks design (RCBD) as outlined by (Robert Jeorge Douglas Steel, James Hiram Torrie), no date; Miller *et al.*, 1958). The path coefficient analysis was done as outlined by (Dewey and Lu, 1959).

Ten drought tolerance indices (Table2) were calculated based on grain yield under saline (Ys) and normal soils (Yp) conditions and the stress intensity SI = 1− (Ys/Yp).

Table 2. Physical and chemical properties of the upper 60 cm of the soil in 2018 and 2019

Item	Soil type			
	Normal soil	Saline soil	Normal soil	Saline soil
	Seasons		Seasons	
	2018	2019	2018	2019
Sand%	19%	21%	19	18
Silty%	48%	51%	23	22
Clay%	33%	28%	58	60
Soil texture	Silty clay loam		Silty clay loam	
S.P	67.0	66.0	57	56
PH(1:1)	7.66	7.60	8.6	8.5
O.M	1.68	1.70	1.11	1.20
CaCo3%	3.88	3.90	-	-
EC (mm/cm)	1.65	1.63	13	13.5
SO4 meq/L	2.0	3.0	38.6	37.8
Cl meq/L	4.0	4.0	55.2	54.6
HCO3 meq/L	10.0	9.5	52.4	52.2
Ca+2 meq/L	8.0	7.5	12.6	12.4
Mg+2meq/L	6.0	6.18	59	59.6
Na+ meq/L	2.09	2.25	57	66.2
Total N%	1.6	1.8	1.2	1.4
Total P (ppm)	5.192	5.537	4.192	4.380
Total K (ppm)	223	231	211	205

Table 3. Salinity tolerance indices used for the evaluation of cotton genotypes to saline soil

Salinity tolerance indices	Equation	Reference
Stress susceptibility index (SSI)	[1-(Ys/Yp)]/[1-(Ȳs/Ȳp)]	(Fischer and Maurer, 1978)
Stress tolerance index (STI)	(Yp× Ys)(Ȳp)^2	(Fernandez, 1992)
Mean productivity index (MP)	(Yp+ Ys)/2	(Rosielle and Hamblin, 1981)
Geometric mean productivity (GMP)	(Yp× Ys)^1/2	(Fernandez, 1992)
Stress tolerance index (Tol)	(Yp- Ys)	(Rosielle and Hamblin, 1981)
Yield stability index (YSI)	(Ys/Yp)	(Bouslama and Schapaugh, 1984)
Harmonic mean (HM)	[2(Yp× Ys)]/ (Yp+ Ys)	(Chakherchaman *et al.*,209) Imanparast,
Sensitivity drought index (SDI)	(Yp- Ys)/ Yp	(Farshadfar and Javadinia, 2011)
Drought resistance index (DI)	[Ys ×(Ys/Yp)]/ Ȳs	(Jusheng, 1998)
Relative drought index (RDI)	(Ys/Yp)/(Ȳs/Ȳp)	(Fischer *et al.*, 1998)

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

Ȳp and Ȳs: mean seed cotton yield of all genotypes in non-stress and stress conditions, respectively.

3. Results and Discussion

3.1. Tolerance of Egyptian cotton genotypes to salinity

3.1.2. Means and variances

The analysis of variance (Tables 4 and 5) revealed insignificant differences between years for all traits under saline and normal soils indicating the stability of the studied genotypes over years. Under saline soil the differences among genotypes were significant (P≤ 0.05 or P≤ 0.01) in one year and in the combined analysis for SCY/P, LY/P, SI, NS/B, PH, and Pressley index. While for the BW, the genotypes

Table 4. Mean squares of the studied traits for year1(y1), year2 (y2) and their combined under saline soil

S.V.	df	SCY/P	LY/P	Lint%	NB/P	BW	SI	NS/B	LI	DFF	PH	Mic	UHM	PI
							Year 1							
Reps	2	4.35	1.25	0.73	1.16	0.004	0.05	0.95	0.08	4.06	8.83	0.218	0.11	0.09
Genotype	14	39.87	5.42	0.43	7.87	0.06*	0.12	3.45*	0.11	2.05	12.79	0.03	0.09	0.14*
Error	28	23.72	3.02	0.91	5.20	0.02	0.07	1.27	0.10	3.13	7.20	0.048	0.06	0.058
							Year2							
Reps	2	60.14	6.13	0.65	20.17	0.001	0.006	0.05	0.07	3.08	8.23	0.01	0.01	0.11
Genotype	14	47.54*	6.47**	0.20	6.02	0.04*	0.12*	2.13	0.07	2.40	17.19*	0.02	0.07	0.07
Error	28	15.66	1.87	0.17	5.61	0.02	0.07	1.63	0.04	2.77	5.28	0.03	0.06	0.05
							Combined							
Years(Y)	1	0.30	0.11	0.12	0.05	0.01	0.15	0.19	0.04	0.72	10.25	0.02	0.06	0.02
Reps/years	4	32.25	3.69	0.69	10.66	0.01	0.03	0.51	0.08	3.57	8.54	0.11	0.06	0.09
Genotypes(G)	14	86.5**	11.97**	0.47	12.98	0.11	0.23**	5.14**	0.18**	4.06	23.97**	0.05	0.15	0.19*
YxG	14	0.92	0.10	0.16	0.92	0.01	0.02	0.44	0.01	0.40	6.21	0.01	0.02	0.03
Error	56	19.69	2.45	0.54	5.41	0.02	0.07	1.45	0.07	2.96	6.25	0.04	0.07	0.06

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

Table 5. Mean squares of the studied traits for year1(y1) , year2 (y2) and their combined under normal soil

S.V.	df	SCY/P	LY/P	Lint%	NB/P	BW	SI	NS/B	LI	DFF	PH	Mic	UHM	PI
							Year 1							
Reps	2	1.13	0.04	0.02	2.97	0.02	0.001	2.04	0.028	2.02	6.75	0.01	0.09	0.14
Genotype	14	701.92**	129.6**	0.15**	50.27**	0.15**	0.57**	2.84	0.29**	61.18**	45.59*	0.06	1.08**	0.11
Error	28	72.08	11.77	0.24	8.11	0.04	0.09	1.43	0.06	5.35	14.04	0.04	0.16	0.07
							Year2							
Reps	2	77.38	9.59	0.02	6.70	0.05	0.0002	2.02	0.005	12.68	4.2	0.01	0.12	0.12
Genotype	14	787.18**	141.23**	0.15**	85.85**	0.05*	0.37*	2.34*	0.25**	20.32**	72.57**	0.03	0.58**	0.08
Error	28	69.98	9.78	0.25	11.80	0.02	0.05	0.88	0.05	3.28	18.2	0.04	0.10	0.05
							Combined							
Years(Y)	1	0.01	0.34	0.57	0.09	0.01	0.03	0.03	0.13	40	38.75	0.09	0.3	0.04
Reps/years	4	39.28	4.82	0.23	4.85	0.04	0.01	2.04	0.02	7.36	5.5	0.01	0.11	0.13
Genotypes(G)	14	1468.98**	268.15**	4.20**	123.36**	0.14**	0.37**	3.18*	0.5**	67.17**	106.66**	0.09	1.59**	0.19*
YxG	14	20.13	2.66	0.58*	12.77	0.06	0.05	2.01	0.05	14.34**	11.52	0.01	0.09	0.01
Error	56	71.03	10.78	0.25	9.96	0.03	0.07	1.16	0.06	4.32	16.12	0.05	0.14	0.06

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

differed significantly in both years and combined analysis. Otherwise, the other traits showed insignificant differences among genotypes. Under normal soil, the genotypes expressed their potential and differed significantly (P≤ 0.05 or P≤ 0.01) in all traits except for Micronaire reading, NS/B in one year and Pressley index in both years. These results proved that the genotypes expressed their potentiality under good environments. (Ali *et al.*, 2014) found significant differences among genotypes, environment, and their interaction for all characters except for cotton yield. (Ibrahim *et al.*, 2014) noted that the adaptability estimates indicated that Giza 80 yielded below average and poorly adapted to all environments. However, the promising strain [G.83 x (G .75 x 5844)] x [G.83 x (G .72 x Dandara)] was above average mean yielding ability and well adapted and stable to all environments. The remaining commercial cultivar Giza 90 and the promising strain (G.90 × Australy) showed average stability. Ullah *et al.* (2015) evaluated nine cotton cultivars and found significant (P≤ 0.01) differences for the investigated parameters. (Shaker, 2017) studied different genotypes of Egyptian cotton for stability and found significant differences for genotypes, environments, and their interaction for all characters, except for fiber strength. The effect of soil salinity was clear on all the studied cotton characteristics, but the intensity of the effect differed from one trait to another and from cultivar to another (Table 6).

Table 6. Minimum (Min) and maximum (Max) combined means and reduction% (Red%), the best (BG) and the lowest performance genotype (LG) under normal soil (N) and saline soil (S) for the studied traits

Item	SCY/P,g			BG	LG	LY/P,g			BG	LG	Lint%			BG	LG
	Min	Max	mean			Min	Max	mean			Min	Max	mean		
N	66.25	124.07	88.48	C	Ash	28.8	49.81	33.56	C	B	36.89	40.15	37.81	C	H
S	39.36	51.37	44.47	A	G85	13.88	17.92	15.33	B	H	34.09	35.12	34.46	B	H
Red%	37.18	62.21	48.75			43.11	67.38	53.21			7.17	13.72	8.82		
	NB/P					BW,g					SI,g				
N	27.25	44.50	33.10	C	Ash	2.48	2.93	2.67	A	B	8.80	10.28	9.30	G80	H
S	19.75	24.31	22.03	G	Ash	1.88	2.35	2.02	B	O	8/07	8.77	8.53	J	D
Red%	14.55	52.25	32.47			15.57	33.71	24.07			2.41	21.56	8.02		
	LI,g					NS/B					DFF				
N	6.03	7.19	6.65	C	G80	16.82	19.43	17.87	F	J	67.83	80.33	76.51	B	E
S	6.04	6.54	6.17	D	Ash	14.51	17.70	15.55	B	I	58.17	60.67	59.82	A	J
Red%	-8.37	11.16	5.68			-1.87	23.91	12.93			13.76	26.30	21.68		
	Ph,cm					Mic					UHM,mm				
N	159.5	171.83	166.32	C	F	3.88	4.30	4.11	C	O	31.57	33.33	32.07	B	M
S	71.00	76.17	73.25	J	A	3.60	3.83	3.65	D	O	31.52	32.07	31.77	A	E
Red%	53.28	58.50	55.92			7.30	15.92	11.22			-2.78	4.00	0.89		
	PI														
N	9.32	9.83	9.60	C	H										
S	8.75	9.07	8.62	C	G										
Red%	2.36	11.38	6.63												

A=G95, B=G90, C=G90xAus, D=G80, E=G83, F=G85, G= (G90x Aus) x(G85), H=Ashmouni, I=Dandara, J=(G91xG90xG80), K=(G90xAusxG83xG80xDandara), L=(G90xAusxG83xG72xDandara), M=Karashinki, N=(G90xAusxG83xG75x5844), O=Australian, Red%= (performance under normal- performance under)/ performance under normal x100

The effect of soil salinity expressed as Red% was very high on yield. The severe effect was observed for PH (55.92%), LY/P (52.21%), SCY/P (48 75%) and NB/P (32.47%), while LI (5.68%), Micronaire reading (11.22%), Pressley index (6.63%) and UHM length (0.89%) showed little effects of salinity. Salinity affected lint yield rather than seed. Micronaire reading measures fineness between cultivars and maturity within a cultivar. Therefore, the soil salinity affected the deposition of cellulose. Hence, the strength was affected to some extent, while the length of the fibers was not affected. The Pressley index was less affected than the Micronaire reading due to the number of hairs per unit weight. Abdelraheem *et al*. (2018) reported that drought under greenhouse and field conditions and salt stress in the greenhouse reduced cotton plant growth at the seedling stage, and decreased lint yield and fiber quality traits in the field. (Manikandan *et al.*, 2019) showed that salinity impaired the cotton growth, nutrient imbalance, and seed cotton yield as well as fiber quality under saline conditions. Under salinity, the behavioral pattern was not same at all stages (seed germination, seedling emergence, vegetative growth, squaring, flowering, boll initiation and development) of cotton. Ahmed *et al.* (2019) noted that drought and salinity stresses, alone or in combination, caused significant reduction in plant growth, chlorophyll content and photosynthesis in two cotton genotypes, with the largest impact visible under combined stress. Razaji *et al.* (2020) noted that with increasing salinity stress, yield and number of bolls decreased. In general, the results of this study showed that salinity stress reduced yield of cotton by reducing the number of bolls and caused early maturity. The combined mean over years indicated that the cultivars “G 90 × Aus”, G95, G 90, G 80, and G 83 showed the highest performance in SCY/P, LY/P, Lint%, NB/P and NS/B either under normal or saline soil. Concern DFF the salinity enhanced flowering, since the mean DFF decreased under normal soil from 76.51 to 59.82 under saline soil (Table 6). The earliest cultivars were G90 under normal soil, and G95 under saline soil. The results indicated wide range in DFF under normal soil (67.83 to 80.00), while it was narrow under saline soil (58.17 to 60.67). The Micronaire reading decreased for all cultivars by salinity. The reduction% ranged from 7.30 to 15.92% with an average of 11.22%. It should be noted that the Egyptian cotton cultivars could be considered pure lines, and the intrinsic fineness (hair perimeter and diameter) of each cultivar is almost constant and least affected by environment. Therefore, the reduction in Micronaire reading caused by salinity for a cultivar reflects the low deposition of cellulose, in other words decrease in maturity which caused low depression in strength.

3.1.3. Salinity Tolerance Indices

The stress tolerance indices (SSI, STI, MO, GMP, TOL, YSI, HM, SDI, DI and SDI) were calculated based on the combined mean of SCY/P under normal soil and SCY/P under stress of saline soil and ranked (Table 7). The low rank indicates tolerance and the high indicates susceptibility to salinity. The rank of mean was the lowest for Giz90 x Aus followed by Giza 90 indicating tolerance to salinity stress. These genotypes ranked from the first or the second for salinity tolerance indicators Yp, STI, MP, GMP, HM and DI. Therefore, STI, MP, GMP, HM and DI detected both of tolerant and susceptible genotypes and could be considered.

the best tolerant indices. The cultivar (G90*Aus)*G83*G75*G80*Dandara gave low mean rank, but it showed low yielding. It is worth noting that for the same cultivar the rank varied greatly from one parameter to another. Fouad (2018) in wheat indicated that STI, MP and GMP were the more efficient drought tolerance parameters in identifying high yielding genotypes under normal and drought stress conditions. (Yehia and El-Hashash, 2019) in 24 cottons (*G. barbadense* L.) studied the ability of 13 drought tolerance indices and noted that MP, GMP, STI, YI (yield index) and HM were the most efficient indices to detect drought tolerance genotypes.

Table 7. Rank of drought tolerance parameters, average (R), standard deviation (SDR) and total of average and standard deviation (RS)

Genotype	Yp	Ys	SSI	STI	MP	GMP	TOL	YSI	HM	SDI	DI	RDI	R	SDR	RS
G95	4	7	14	1	4	4	13	14	4	14	4	14	8.08	5.21	13.30
G90	2	2	12	2	2	2	14	11	1	11	2	11	6.00	5.19	11.19
G90xAus	1	1	8	1	1	1	12	8	2	8	1	8	4.33	4.10	8.43
G80	3	5	4	3	3	3	15	15	3	15	3	15	7.25	5.75	13.00
G83	5	9	10	5	5	11	10	6	10	10	5	9	7.92	2.47	10.38
G85	8	13	2	8	8	8	1	2	15	2	8	2	6.42	4.64	11.06
(Giza90×Aus) × G.85	12	10	4	12	12	12	3	4	12	4	12	6	8.58	3.96	12.55
Ashmouni	15	6	5	15	15	15	6	5	7	5	15	7	9.67	4.75	14.42
Dandara	14	11	11	14	4	14	10	13	10	13	14	13	11.75	2.90	14.65
(G.91×G.90×G.80)	11	4	7	11	11	11	7	7	5	7	11	5	8.08	2.75	10.83
G11	7	3	1	7	7	7	2	1	8	1	7	1	4.33	3.03	7.36
G12	6	14	9	13	13	13	8	9	11	9	13	10	10.67	2.53	13.20
Krashinki	9	12	6	9	9	9	4	6	14	6	12	3	8.25	3.36	11.61
G14	13	15	13	6	6	6	9	12	13	12	6	12	10.25	3.41	13.66
Australian	10	8	3	10	10	10	5	3	9	3	10	4	7.08	3.18	10.26

G11=promising genotype (G90*Aus)*G83*G75*G80*Dandara, G12=(G90*Aus)*G83*G72*Dandara, G14=(G90*Aus)*G83*G75*5844.

3.1.4. Correlations among traits

3.1.4.1. Genotypic correlation among traits

The genotypic correlations among the studied traits from the combined data of the two seasons under normal and saline soils are shown in Table 8. Under normal soil the genotypic correlation of SCY/P was high and positive with LY/P, NB/P, BW, Lint% and SI, it exceeded the unity with BW due to the minimal estimates of genotypic variance of boll weight (the denominator of correlation). While it was moderate for both of PI (Pressley index) and Micronaire reading, and low negative with DFF and UHM length. Under saline soil the correlations with SCY/P were in the same trend as normal soil except with SI which decreased, while NS/B increased under saline soil. This means that SCY/P under saline soil depended on number of seeds rather than seed weight. Furthermore, the high yielding plants under saline soil were early in maturity. The three fiber properties, their correlations with SCY/P were higher than under normal soil. The correlations of different traits with LY/P showed the same picture as with SCY/P. Under normal soil the plants were healthy and gave large number of bolls of high weight. Therefore, the correlation of NB/P was high with BW, lint% and SI, and positive with Micronaire reading (0.443) and Pressley index (0.323). Under saline soil the correlations of NB/P were lower either positive or negative than under normal soil. Furthermore, under poor nutrition NB/P gave negative correlations with both BW and SI. Under the good environment the correlation of BW was high with lint% (0.904), SI (0.802), Micronaire reading (1.00) and Pressly index (0.577). Under the saline soil, correlations of BW were high with lint% (0.949), NS/B (0.881) and Micronaire reading (0.707), and negative with DFF (-0.634). It could be noticed that under saline soil conditions, the weight of the boll depended on the number of seeds rather than their weight, and the deposition of cellulose was less than under normal soil, which decreased the correlation of the Micronaire reading with BW from 1.00 under normal to 0.707 under saline soil.

Seed index showed negative correlations with LI and NS/B under both environments. Seed index gave negative correlations with fiber properties under poor and positive under good environment.

Table 8. Genotypic correlation coefficients under normal soil (above diagonal) and under saline soil (below diagonal) among the studied traits over the two years

Traits	SCY/P	LY/P	NB/P	BW	SI	LI	NS/B	Lint%	DFF	MIC	UHM	PI	PH
SCY/P		0.998	1.000	1.145	0.623	0.164	0.249	0.934	-0.179	0.489	-0.227	0.331	0.224
LY/P	0.999		1.004	1.112	0.583	0.213	0.156	0.953	-0.149	0.511	-0.256	0.526	0.214
NB/P	0.665	0.631		1.141	0.598	0.198	0.266	0.956	-0.283	0.443	-0.168	0.323	0.332
BW	0.599	0.608	-0.1		0.802	0.354	0.224	0.904	0.202	1.000	-0.400	0.577	-0.126
SI	0.106	0.107	-0.141	0.354		-0.661	-0.538	0.345	-0.288	0.267	0.053	0.463	0.309
LI	0.183	0.207	0.163	0.408	-0.866		0.791	0.502	0.369	0.354	-0.354	-0.408	-0.231
NS/B	0.633	0.655	-0.096	0.881	-0.057	0.392		0.375	0.716	0.447	-0.626	-0.129	-0.741
Lint%	0.817	0.833	0.189	0.949	-0.224	0.516	0.962		0.126	0.645	-0.387	0.149	0.062
DFF	-0.654	-0.688	-0.199	-0.634	0.192	-0.517	-0.768	-0.973		0.606	-0.761	-0.584	0.360
MIC	0.318	0.286	0.282	0.707	-0.500	0.577	0.34	-0.447	-0.384		-0.400	-0.577	0.402
UHM	0.674	0.709	0.100	0.500	-0.354	0.408	0.801	0.949	-0.634	0.707		0.462	-0.547
PI	0.566	0.579	0.122	0.408	-0.289	0.333	0.719	0.516	-0.813	0.577	0.408		0.130
PH	0.241	0.201	0.449	0.165	0.555	0.371	0.06	0.287	0.105	0.526	0.041	0.18	

The correlations of LI were positive with NS/B and lint% under both environments.

Under poor environments the late mature plants usually were poor in growth and in boll number and weight. Therefore, DFF was negatively correlated with SCY/P, LY/P, NB/P, BW, LI, NS/B, lint% and fiber properties. However, under good environment DFF gave positive correlations with LI, NS/B, lint% and Micronaire reading.

Such very complicated relationships the results could be summarized as:

1- Under both environments the correlations among SCY/P, LY/P, NB/P, BW, and lint% were positive except for NB/P and BW under saline soil.

2- Negative correlation was found between LI and SI under both environments.

3- Positive correlation was observed between LI and NS/B.

4- Positive correlations were found between BW and NS/B, lint%, SI and LI.

5- DFF gave negative correlations with all traits except SI under saline soil, and LI, NS/B, lint%, and Micronaire reading at normal soil.

6- Micronaire reading showed positive correlations with all traits except PI and UHM length under normal soil, and lint%, SI and DFF under saline soil.

7- The correlations of UHM length were positive except SI, DFF under saline soil and negative with all except PI under normal soil.
8- Pressley index showed positive correlations with all traits except DFF and SI under saline soil, and LI, Micronaire reading and DFF at normal soil.

These results are in line with those reported by many authors. Mahdi and Emam (2020) in Egyptian cotton indicated that days to the first flower showed a negative correlation with seed cotton yield per plant. Shehzad *et al.* (2019) revealed that seed cotton yield had a significant positive correlation with plant height, number of bolls per plant, lint%, staple length and fiber strength. Staple length and fiber strength were negatively linked with each other. (Chapepa *et al.*, 2020) found that seed cotton yield was correlated with lint yield, bolls per plant, seed weight, strength, lint% and fineness at genotypic level. Ginning outturn was correlated with lint yield, and strength. Boll weight was correlated with seed weight.

3.1.4.2. Path coefficient analysis

Path analysis, as proposed by (Wright, 1921), allows for a better understanding of different trait associations. It provides an effective means of partitioning correlation to direct and indirect effects , thus permitting a critical examination of specific factors that produce a given correlation (Shazia Salahuddin *et al.*, 2010), and helps the breeder to restrict selection for few important traits and reduce time and effort (Wadeyar and Kajjidoni, 2014). Therefore, the cotton breeders are looking for traits used as potential selection criteria with yield to develop high and stable genotypes. The genotypic correlation coefficients of seed cotton yield with its contributing traits were partitioned to direct and indirect effects and shown in Table 9. Seed cotton yield / plant results from lint yield / plant, bolls / plant, number of seeds/boll and seed index.

The correlation coefficient of lint yield / plant with seed cotton yield / plant (Table 8) was positive and very large in magnitude (0.9970) under normal soil, and 0.998 under salinity stress. However, the direct effect of LY/P on SCY/P was moderate (0.401) under normal soil, and high (0.802) under salinity stress. NB/P showed indirect effect of 0.484 under normal soil and low and negligible under salinity stress (0.101). Furthermore, NS/B and SI had negligible indirect effects under both environments. Therefore, LY/P and NB/P should be considered in selection for SCY/P under normal soil, and for LY/P only under salinity stress.

The correlation coefficient of NB/plant with seed cotton yield / plant was .961 under the good environment and .646 under the bad one. The direct effect of BW was 0.507 under good and 0.178 under salinity stress. However, LY/P indirectly plays an important role under both environments. The other indirect effects of NS/B and SI were very low or negative. This confirms that selection for SCY/P should depend on LY/P and NB/P under good and on LY/P under bad environments.

Partitioning correlation of NS/B with SCY/P (0.136) indicated that the direct effect of NS/B was 0.147 under normal soil conditions, while the other indirect effects of LY/P, NB/P and SI on SCY/P via NS/B were low and negligible. Otherwise, the indirect effect of LY/P on SCY/P via NS/B was high (0.506). The other indirect effects of NB/P and SI on SCY/P via NS/B were low and negative.

Partitioning correlation of SI with SCY/P (0.603) under the normal soil, the direct effect was 0.153, while the indirect effects of LY/P and NB/P on SCY/P via SI were 0.229 and 0.262, respectively. Under saline soil the direct effect of SI was 0.050 and the indirect effects of LY/P, NB/P and NS/B on SCY/P via SI were 0.085 and 0.-0.24 and -0.006, respectively.

Table 9. Path coefficient analysis under normal soil and salinity soil conditions

Item	Normal soil	Saline soil	Item	Normal soil	Saline soil
SCY/P *vs* LY/P	r=0.997	r=0.998	SCY/P *vs* NB/P	r=0.961	r=0.646
Direct effect, P15	0.401	0.802	Direct effect, P25	0.507	0.178
Indirect effect, NB/P	0.484	0.109	Indirect via LY/P	0.383	0.495
Indirect effect, NS/B	0.023	0.080	Indirect via NS/B	-0.0089	-0.019
Indirect effects, SI	0.087	0.005	Indirect via SI	0.079	-0.006
Total	0.997	0.998	Total	0.507	0.646
SCY/P *vs* NS/B	r=0.136	r=0.604	SCY/P *vs* SI	r=0.603	r=0.105
Direct effect, P35	0.147	0.128	Direct effect, P45	0.153	0.050
Indirect via LY/P	0.062	0.506	Indirect via LY/P	0.229	0.085
Indirect via NP/B	-0.030	-0.027	Indirect via NB/P	0.262	-0.024
Indirect via SI	-0.043	-0.002	Indirect via NS/B	-0.041	-0.006
Total	0.136	0.604	Total	0.153	0.050

4. Conclusion

It could be concluded that the direct and indirect effects of SCY/P components varied greatly under both environments. The direct effects of the SCY/P components under normal soil were 0.504, 0.401, 0.153 and 0.147 for NB/P, LY/P, SI, and NS/b, respectively. However, under saline soil the direct effects were 0.802, 0.178, 0.128 and 0.050 for LY/P, NB/P, NS/B and SI, respectively. Therefore, under both environments, selection should be paid mainly on NB/P and LY/P. Farooq *et al*. (2014) found positive direct effect of boll weight on seed cotton yield / plant. (Majeedano *et al.*, 2014) found that bolls plant-[1] had maximum direct effect (0.945) followed by the boll weight (0.062), seed index (0.007) and lint index (0.040). (Wadeyar and Kajjidoni, 2014) and noted that the correlation and path analysis together indicated that number of bolls / plant and boll weight should be considered when selection practiced for seed cotton yield / plant. (Joshi and Patil, 2018) found that number of bolls/plants had positive indirect effect on seed cotton yield/plant, seed index, lint index, fiber strength etc. Boll weight was responsible for high yield through seed index and lint index.

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