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# Stability Analyses of Early Segregating Egyptian Cotton Populations and Their Parents Across different Irrigation Intervals and Sowing Dates.

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## ABSTRACT

This research was conducted to explore the potentiality of variable $F_2/F_3$ cross combinations and their six parents for developing climatic resilient genotypes under a wide range of environmental conditions. During 2019 and 2020 seasons, eight RCBD trials were carried out at the Faculty of Agriculture, Minia University, using two planting dates as early, (onset of April) and late planting, (onset of May). In each sowing date, two trials were conducted by irrigation each 14 and each 28 days as normal and stressed, respectively. Combined analysis showed that cotton genotypes, environments, and their interactions (GEI) were highly significantly for all traits with considerable magnitudes of GEI than other sources of variance. G.90CB58 exhibited the sole desirable parent for significantly highest seed cotton yield (SCY) and stability estimates with expected response to favorable environments. G.90CB58 shared Australian for better performance and stability the lint yield (LY). The cross combinations of G.90 with G.94, G.95 and Karashanky recorded significantly higher SCY and LY with somewhat stability in performance despite none of common parents exhibited similar superiority. The crosses of G.94 with G.90CB58 & Australian produced significantly higher SCY and LY with promising stability. The combinations of G.95 with G.90CB58 in addition to those of G.95 with Austalian recorded significantly the highest SCY and LY with simultaneously resilient performance to different environmental conditions. It could be concluded that these eight out of studied fifteen cross combinations may be considered as encouraging resources for selecting promising higher SCY and LY accompanied to desirable stability

***Keywords:*** Egyptian cotton, GEI, Stability analyses, Climate change, Crop resilience.

## INTRODUCTION

Egyptian cotton (*Gossypium barbadense* L.) is one of the most important strategic crops in Egypt. In the 2021 season, the cultivated area was about 237.5 thousand feddan (98.960 hectares) produced about 596.572 bales (CATGO 2021). One of the most complicated issues facing any crop breeding program/s is the effective determination of high yielding genotype coupling with stable/resilient in performance across wide range of environmental conditions. The attention for quality of lint and oil production couldn't neglected in cotton breeding activities. Analysis of yield stability has become more important in recent years since the recognition of climate change effects, CCE (Najafi *et al*., 2018). Drought and heat stress are the major outcomes of CCE that adversely affect growth, phenology, yield, and fiber quality (Pettigrew, 2004 and 2008). Under water deficit stress conditions, the cotton seed yields may be decreased up to 33.9 % in comparison to well-watered conditions (Mahdy *et al*., 2021). Late sowing push cotton plants to early flowering and maturity, and consequently decreased cotton yield mainly due to reduction in boll weight and number of open bolls (Elayan *et al*., 2015). The optimum recommended sowing time of Egyptian cotton ranging from 15 to 30 March, but it may be delayed to the onset of April after harvesting the proceeded winter crops (Baker and Eldessouky, 2019).

The tolerance/resistance or resilience of the recent cotton varieties to unpredicted environmental conditions generated from CCE is crucial for their stable in performance. Cotton plants are known as sensitive to micro-environmental conditions (Reddy *et al.* ,1995). They defined these conditions included soil moisture, air temperature, and relative humidity through periods from sowing to picking which exert their effects on growth, earliness, yield, and yield components, as well as fiber quality. A lint yield dropped up to 10% with raising each 1°C in maximum day temperature (Pettigrew, 2008). Seed and lint cotton yield/plant and fiber quality traits except micronaire reading were decreased due to water stress (Abdel-Monaem *et al.*, 2018). Genotype by environment interaction (GEI) may be expressed the resilience of performance of a genotype or a given trait across environments. GEI illustrates that not only the genetic potential of a genotype but also, its interaction with environmental factors (soil type, climate fluctuations, planting methods, management technology, etc.) affect the phenotypic expression the genetic background. Promising genotypes need to be evaluated in the multi-environmental tests over several years to determine their stability and the extent of adaptation. Genotype stability has a vital role and simply means how consistent the yield of a genotype is compared with other genotypes. However, Eberhart and Russell (1966) postulated that genotype/s with minimal interaction with the environmental indices could be regarded as stable genotypes.

The common parametric parameter used for detecting the nature of GEI is the linear regression model of

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(Eberhart and Russell, 1966), in which $b_i$ give information about adaptability, and $S^2d$ is used as a measure of the stability of performance. Non-parametric procedures proposed by Kang (1988 and 1993) are based on the ranks of genotypes within each environment, and the genotypes with similar ranking across all environments are classified as stable. The rank-sum (Rs) and simultaneous selection for yield and stability (YSi) were widely used as selection criteria due to both considered both yield and stability and enables the identification of high-yielding and stable genotypes. Recently cotton breeders used different stability methods to estimate GEI through multilocation trials for Egyptian cotton genotypes under different environments (Khalifa *et al.*, 2010; Dewdar, 2013; Said, 2016; Gibely and Hassan, 2018; Shaker *et al*., 2020 as well as Said and Hefny, 2021).The capability of various parametric and non-parametric stability concepts for identification the extent stability and their interrelationships may be violated due to lacking data normality and or homogeneity of error terms (Kang,1988).

Thus, the aims of the present investigations are to evaluate the precision of some parametric and nonparametric stability measurements for screening different cotton genotypes. The potentiality of early segregating Egyptian cotton populations possessing variable genetic combinations along to their parents under a wide range of environmental conditions of soil moisture and climatic features may be valuable for developing new climatic resilient cotton varieties.

## MATERIALS AND METHODS

Fifteen $F_2/F_3$ segregating populations of Egyptian cotton genotypes along with their parental varieties were evaluated under eight field experiments during 2019 ($F_2$-generations plus parents) and 2020 ($F_3$-generation along to their parents) summer seasons at the Agricultural Experiments and Research Farm of the Faculty of Agriculture, Minia University, El-Minia, Egypt. These populations were stemmed from diallel mating system (Taha *et al*., 2018). The codes, pedigree, and source of the six parental Egyptian cotton genotypes are presented in Table 1. In each season, four separate trials were carried out using two planting dates i.e., April 7th (as early planting) and May 7th (as late planting). In both dates of sowings, two separate trials were conducted using two irrigated watering regimes as normal (each 14 days intervals), but the second had been irrigated every 28 days (as water stressed). Each trial was conducted as RCBD with three replications with single-ridge plot size, each was four meter long and 65 cm wide (2.6 $m^2$). The seeds were dry planted at one side of the ridge in hills distanced 25 cm and seedlings were thinned to two plants /hill after six weeks from planting. Other recommended agronomic and cultural practices for cotton production at El-Minia region were adopted in all experiments. Seed cotton yield (SCY), lint cotton yield (LY), lint percentage (L%), seed index (SI), lint index (LI), and boll weight (BW) were recorded using ten guarded plants chosen randomly from each plot.

**Table 1. Code, name, pedigree, and sources of the six parental Egyptian cotton genotypes.**

| Parent Code | Name | Pedigree | Some features |
|---|---|---|---|
| P1 | Giza 90 (G.90) | G.83x Dandara | Long-staple, high yield and lint percentage, old recommended variety for Upper Egypt. |
| P2 | Giza 94 (G.94) | G86 x 10229 | long staple, earliness and high yield, strong lint, and fiber fineness recommended variety for North Delta |
| P3 | Giza95 (G.95) | [(G.83 × (G.75 × 5844)) × G.80] | High yielding ability, high lint percentage, earliness, and heat tolerance, recently recommended variety for Upper Egypt |
| P4 | Karashanky (Kar.) | Un Known | Russian exotic genotype promising in Egypt for early maturity and high boll number. |
| P5 | (G.90CB) | G90 ×C. B58 | Promising line of national cotton program for long staple Characterized by earliness, high yielding ability, high lint percentage. |
| P6 | Australian (Aust.) | [(G83×G80) ×G89] × Australian | Promising variety from Shandaweel station introduced for accreditation due to heat tolerance and high yield production for Upper Egypt. |

### 1. Soil Physical Analysis

The mechanical analyses of experimental soil were conducted in the soil lab of the soil science Dept. Fac., Agric., Minia University, revealed that the soil texture of the experimental site is clay loam. The percentages of clay, silt, and sand were 54.7, 35.3, and 9.9, respectively with pH 7.9. The timetable irrigation and depleted soil moisture percentages during the 2019 and 2020 summer seasons are presented in Table 2.

**Table 2. Timetable of irrigation and depleted soil moisture percentages during 2019 and 2020 summer seasons.**

| Season | | $F_2$ (2019) | | | | $F_3$ (2020) | | | |
|---|---|---|---|---|---|---|---|---|---|
| Trial | | EN | ES | LN | LS | EN | ES | LN | LS |
| F.C% | | 40.9 | 39.9 | 39.9 | 40.4 | 39.5 | 37.1 | 38.5 | 36.4 |
| WP% | | 14.6 | 14.2 | 14.3 | 14.4 | 14.1 | 13.5 | 13.7 | 13.0 |
| AW% | | 26.4 | 25.6 | 25.7 | 25.9 | 25.4 | 24.3 | 24.7 | 23.4 |
| Number of days from sowing | 0.0 | 7 April 2019 | | 7 May 2019 | | 7 April 2020 | | 7 May 2020 | |
| | 21 | Mohyaa irrigation | | | | | | | |
| | 41 | 1st irrigation | | | | | | | |
| | 55 | 2nd I13.5AW, 48.8%Dep. | Escape 8.9AW, 63.4%Dep. | 2nd I10.0AW, 61.1%Dep | Escape 9.0AW, 61.5%Dep | 2nd I 6.5AW, 74.2%Dep | Escape 9.1AW, 62.4%Dep | 2nd I 6.8AW, 72.5%Dep | Escape 7.3AW, 68.8%Dep |
| | 69 | 3rd I | 2nd I 2.0AW,91.8%Dep | 3rd I | 2nd I 3.4AW,85.3%Dep | 3rd I | 2nd I 4.7AW,80.7%Dep | 3rd I | 2nd I 3.2AW,86.2%Dep |
| | 83 | 4th I | Escape | 4th I | Escape | 4th I | Escape | 4th I | Escape |
| | 97 | 5th I | 3rd I | 5th I | 3rd I | 5th I | 3rd I | 5th I | 3rd I |
| | 111 | 6th I | Escape | 6th I | Escape | 6th I | Escape | 6th I | Escape |
| | 125 | 7th I | 4th I | 7th I | 4th I | 7th I | 4th I | 7th I | 4th I |
| | 139 | 8th I | Escape | 8th I | === | 8th I | Escape | 8th I | === |
| | 153 | 9th I | 5th I | === | === | 9th I | 5th I | === | === |

**Where: F.C %: Field capacity, WP%: Wilting point, AW%: Available water, I: Irrigation, Dep%: Depletion water, Early sowing of normal (EN) and stress (ES) watering as well as late sowing of normal (LN) and stress (LS).**

**2. Seasonal climatic description**

The agrometeorology data of the El-Minya region during the 2019 and 2020 summer seasons from March 20 to the end of September in 15-day intervals are presented in Figs (1, 2, and 3). Growing degree days (GDD) were calculated as [($T_{max}$ + $T_{min}$)/2] - base Temperature (12.8C°) according to Young *et al.* (1980). These climatic data were kindly supported by Mallawy Agricultural climate Station, El-Minya, Egypt.

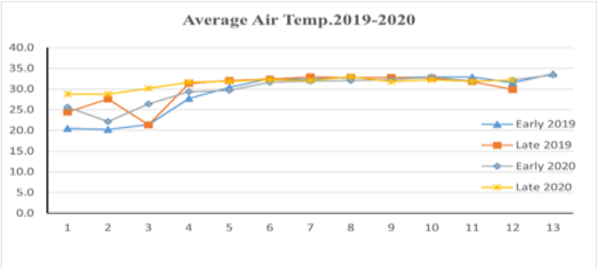


**Fig. 1. Average of air temperature across 15-day intervals of each sowing date trials during 2019and 2020 seasons.**

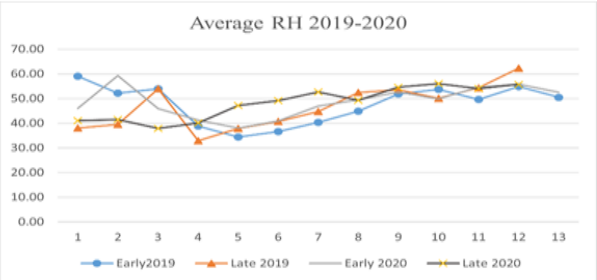


**Fig. 2. Relative humidity (RH) across 15-day intervals of each sowing date trials during 2019 and 2020 seasons.**

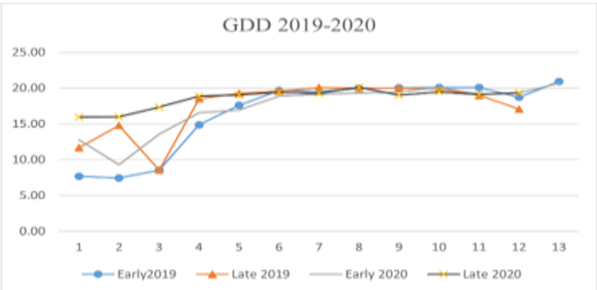


**Fig. 3. Growing degree days (GDD) across 15-day intervals of each sowing date trials during 2019 and 2020 seasons.**

**3. Statistical analyses**

The Randomized complete block design (RCBD) analysis of the obtained data of each experiment was performed summed eight analyses to explore the differences among cotton genotypes in each sowing date or watering regime trials of both seasons. Combined analysis of variance due to cotton genotypes over 8 environments (2 sowing dates × 2 irrigation intervals × 2 seasons) was performed according to Gomez and Gomez (1984).

**Stability analysis**

**The analyses of stability were performed as follows:**

**Parametric stability statistics**

**I-Eberhart and Russell's model**: stability analysis of genotypic performance across eight environments was estimated in case of significant mean squares of G×E interaction calculating two stability parameters as suggested by Eberhart and Russell (1966). These parameters are regression coefficient (bi) and mean squares of deviation from regression ($S^2d_i$) of the performance on environmental indices.

**II-Wricke's ecovalence (Wi):** which is the measure of G×E due to each genotype, squared and summed across environments according to Wricke (1962). The author called this measure ecovalence where a genotype with Wi = 0, is considered stable or low values of ecovalence.

**Non-parametric measures**

**I-Rank-sum (RS): Kang's (1988)**: The rank-sum as a non-parametric stability measure used both yield and stability variance of Shukla's (1972). This parameter gives a weight of one to both yield and stability statistics to identify high-yielding and stable genotypes. The genotype with the highest yield and lower $\sigma^2$is assigned a rank of one. Then, the ranks of yield and stability variance are added for each genotype and those exhibited the lowest rank-sum (RS) are the most desirable genotypes.

**II-Yield-stability statistic ($YS_i$):** This measure was developed for simultaneous selection for yield and stability and could be calculated according to Kang (1993) involves genotype rankings based on $\sigma^2$i (Shukla, 1972) and mean performance rankings after a protected LSD adjustment.

The software GenStat and Excel were used for statistical analysis

## RESULTS AND DISCUSSION

**1. Analyses of variance of each environment and G × E interaction (GEI)**

The magnitudes of mean squares and their significance of the investigated 21 Egyptian cotton genotypes using separate RCBD analysis of normal (N) and stressed (S) irrigation regimes either under early or late sowings during both seasons are presented in Table 3. Each of the studied $F_2$ or $F_3$ segregating cotton populations along to their parents varied highly significant under each of all tested environments for all studied traits, except for BW of $F_3$ generation under early sowing either irrigated normally (EN) or stressed (ES).

**Table 3. Significance of mean squares due to RCBD analyses of either $F_2$ or $F_3$ segregating populations plus parental genotypes (df=20) under four environments during 2019 and 2020 seasons, respectively for yield and yield components.**

| Season | Env.1) | Mean squares | | | | | |
|---|---|---|---|---|---|---|---|
| | | SCY | LY | L% | SI | LI | BW |
| 2019 (F2) | $ENF_2$ | 21.15* | 6.09** | 4.80* | 0.69** | 0.60** | 0.05* |
| | $ESF_2$ | 40.95** | 16.35** | 25.92** | 2.28** | 0.62** | 0.05** |
| | $LNF_2$ | 39.92** | 7.74** | 7.07* | 0.68* | 0.77** | 0.06** |
| | $LSF_2$ | 134.20** | 18.18** | 8.38** | 0.99** | 0.82** | 0.05** |
| 22020 (F3) | $ENF_3$ | 6.40** | 0.85** | 0.28** | 0.06* | 0.10* | 0.04 **ns** |
| | ES $F_3$ | 4.66** | 0.62** | 0.31** | 0.11* | 0.21* | 0.02 **ns** |
| | LN $F_3$ | 35.61** | 5.43** | 1.13** | 0.26** | 0.52* | 0.06* |
| | LS $F_3$ | 34.14** | 4.86** | 0.91* | 0.22** | 0.29* | 0.04** |

**1) E and L indicate early and late sowings, respectively, whereas N and S mean normal and stressed irrigation regimes, respectively.**

**-Ns, *and ** indicate insignificance mean squares, significance at 5% and significance 1%, respectively.**

$F_2$ generation recorded under water stressed trial of early sowing higher variances (ranged from 2 folds to 5 folds) than under normal irrigation for SCY, LY, L% and SI. However, the genotypic variance under such stressed WR of late sowing showed about 3.0 folds as higher as under normal WR of this sowing date only for SCY and LY. On other hand LI and BW of $F_2$ showed somewhat genotypic variances under all four trials of 2019 season in addition to L% and SI under both experiments of late sowing. But F3 generations recorded similar magnitudes of variances between coupled trials (N & S) of each planting dates except for SI and LI of ES showed two folds as higher as of EN like BW of EN compared to ES.

The significance of mean squares of combined analysis across generated eight environments is presented in Table 4. The investigated cotton genotypes varied highly significantly over the environments for all studied cotton yield traits indicating the presence of genetic variation among the investigated parents and segregating populations. Environments as a combination of sowing dates, watering regimes in both seasons affected highly significantly all the studied traits. This means that the generated environmental conditions affected substantially all the studied cotton yield traits. The magnitudes of environmental variations recorded more than 5 folds as of genotypes which an indication of higher environmental effects than those due to genotypic differences.

**Table 4. Significance of mean squares of the combined analyses of the fifteen $F_2/F_3$ segregating cotton populations (plus parental genotypes) over eight environments (experiments) during 2019 and 2020 seasons.**

| S. V | d.f | SCY | LY | L% | SI | LI | BW |
|---|---|---|---|---|---|---|---|
| Genotypes. | 20 | 49.9** | 12.0** | 7.5** | 1.5** | 1.3** | 0.05** |
| Env. | 7 | 7525.1** | 1428.4** | 110.2** | 8.1** | 14.27** | 0.09 ** |
| G×E | 140 | 38.2** | 6.9** | 5.9** | 0.4** | 0.57** | 0.04 ** |
| Env. +(G×E) | 147 | 394.7** | 24.9** | 3.6* | 0.2ns | 0.41ns | 0.06 ns |
| Env. (linear) | 1 | 17558.6** | 3333.0** | 257.1** | 18.9** | 33.29** | 0.77 ns |
| G×E (Linear) | 20 | 4.1ns | 1.6ns | 6.3** | 0.2ns | 0.45ns | 0.03 ns |
| Pooled deviation (NL) | 126 | 320.5** | 2.3** | 1.2* | 0.1** | 0.1** | 0.27 ns |

**Ns, *and ** indicate insignificant, significant at 0.05 and significant at 0.01 level, respectively.**
**NL=nonlinear.**

The G × E interaction (GEI) was highly significant for all analyzed six traits. This proved that the studied genotypes performed differently from one environment to another for these traits.

The variance due to Env. + (G × E) may be partitioned into Env. (linear), G × E (linear), and pooled deviation (nonlinear) from the regression model according to (Eberhart and Russell, 1966). The mean squares due to Env. (linear) which are due to regression were highly significant for all studied traits except BW. However, variances due to G × E (linear) were only significant for L%. But the mean squares due to Env. + (G×E) were highly significant for SCY, LY and L% suggesting that the relative importance of unpredictable component of GEI for determining the degree of stability.

The pooled deviation was significant for all investigated traits except BW. Becker *et al*. (1982) stated that mean square of deviation from regression due to it's a proper reflection of the predictable reaction of the tested genotypes to environmental conditions. Thus, Eberhart and Russel (1969) supported the point of view that deviation from regression is the most proper measure of stability due to it involved all types of gene action.

The obtained significance of GEI for the studied traits proved that the investigated cotton genotypes possessed different degrees of stability/ adaptability. Therefore, it could be valid to further assess the extent of stability in performance of the segregating cotton populations along to their parents to detect which of them are proper for extracting selections that may perform superior across similar of studied environments (different sowing dates accompanied with variable degrees of soil moisture). Kang *et al*. (2004) recommended for assessing the relative stability of genotypes, the analysis of stability statistics is necessary to apply either parametric or non-parametric procedures or both. Thus, the better understanding of the relative contribution of genotypes, environments, and their interaction as a source of variation could potentially help cotton breeders to develop genotypes with more stable in performance.

**2. Mean effects of environments**

The mean performance and environmental index (I) of each environment (sowing date or watering regime) are presented in Table 5. The environmental index used in this table is the deviation of each environment from the grand mean of all environments, and it directly reflects the given environment as poor or favor environments in terms of negative and positive index ($I_{.j}$), respectively. Thus, the early sowing of normal ($ENF_3$) and stress ($ESF_3$) watering regimes in 2nd season may be considered poor environments for all traits except for BW, while these environments in 1st season seemed to be favor environments.

Regarding the SCY and LY, the $ENF_2$, $ESF_2$, $LNF_2$, and $LSF_2$ environments produced higher seed and lint yields than those for 2nd season which reflected in considerable positive environmental indices. The dominated conditions in the first season either planted earlier (during April) or later (in May) produced significantly higher cotton seed (SCY) or lint (LY) yields than those of the second season except the late sowing with normal watering regimes (NWR). These effects resulted in significant positive environmental indices. However, late sowings of both seasons recorded higher positive indices for SCY and LY than earlier ones. On the other hands, SWR (stressed watering regimes) of both sowings and seasons produced relatively lower SCY or LY than NWR as evidenced of lower magnitudes of $I_{.j}$. Contradicting performance could be observed for lint percentages (L%) of lower environmental indices despite lacking significance with early sowing and normal irrigation ($ENF_2$).

Pertaining to seed (SI) and lint (LI) indices, the early sowing with normal or stressed watering regimes ($ENF_2$ and $ESF_2$) produced the highest seed and lint index than under other tested environments which reflected in positive environmental indices. On the other hand, the mean performance of boll weight (BW) almost remained constant across tested environments which reflected in negative environmental indices.

**Table 5. Mean performance and environmental index (I.j) of tested environments over investigated Egyptian cotton genotypes for studied cotton characters from combined analysis.**

| Env. | SCY | | LY | | L% | | SI | | LI | | BW | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | I.j | Mean | I.j | Mean | I.j | Mean | I.j | Mean | I.j | Mean | I.j |
| $ENF_2$ | 62.8 | 7.9** | 25.0 | 3.0** | 39.8 | -0.2ns | 9.9 | 0.8** | 6.6 | 0.4** | 2.8 | 0.0 ns |
| $ESF_2$ | 58.7 | 3.8** | 24.8 | 2.8** | 42.3 | 2.3** | 9.4 | 0.3** | 7.0 | 0.8** | 2.7 | 0.0 ns |
| $LNF_2$ | 63.3 | 8.4** | 25.7 | 3.7** | 40.6 | 0.6** | 9.1 | 0.0ns | 6.2 | 0.1ns | 2.8 | 0.1 ns |
| $LSF_2$ | 61.5 | 6.6** | 25.4 | 3.4** | 41.4 | 1.4** | 8.9 | -0.3** | 6.3 | 0.2ns | 2.7 | -0.1 ns |
| $ENF_3$ | 39.3 | -15.6** | 15.2 | -6.8** | 38.7 | -1.2** | 8.8 | -0.4** | 5.6 | -0.6** | 2.8 | 0.0 ns |
| ES $F_3$ | 36.7 | -18.2** | 14.2 | -7.8** | 38.6 | -1.4** | 9.0 | -0.1ns | 5.7 | -0.4** | 2.7 | -0.1 ns |
| LN $F_3$ | 63.3 | 8.4** | 25.0 | 3.0** | 39.6 | -0.4* | 9.0 | -0.1ns | 6.0 | -0.2ns | 2.7 | 0.0 ns |
| LS $F_3$ | 53.5 | -1.4** | 20.8 | -1.2** | 38.9 | -1.1** | 9.0 | -0.1ns | 5.8 | -0.4** | 2.8 | 0.0 ns |
| $L.S.D_{0.05}$ | 1.5 | 0.7 | 0.7 | 0.4 | 0.8 | 0.4 | 0.18 | 0.2 | 0.23 | 0.3 | 0.07 | 0.2 |
| $L.S.D_{0.01}$ | 2.0 | 0.9 | 0.9 | 0.5 | 1.0 | 0.5 | 0.24 | 0.3 | 0.31 | 0.3 | 0.09 | 0.3 |

**Ns, *and ** indicate significant differences between each environmental mean and the grand mean of environments {L.S. D= $t\alpha \times \sqrt{\frac{MSe}{r\times g}+\frac{MSe}{r\times g\times e}}$ }**

### 3. Stability of performance of Egyptian cotton genotypes

Three parametric stability ($b_i$, $S^2d_i$, and $W_i$) and two non-parametric (RS, and $YS_i$ ) stability statistics were used for measuring stability of the $F_2/F_3$ cotton populations and their parents that will be considered for seed cotton yield (SCY) and lint yield (LY) traits.

The $S^2d_i$ was proposed as a parameter of stability and bi as a measure of response according to (Eberhart and Russell, 1966). In the case of a genotype has insignificant $S^2$di from zero, indicates it's stable in performance, whereas the significance of $b_i$ either less than unity (b>1) or more than unity (b<1) proved that the genotype is responsive to unfavorable or favorable environments, respectively. However, ecovalence ($W_i$) as a parameter of stability, measures the extent of GEI due to each genotype (Becker and Léon, 1988). The mean performance and estimated stability parameters of the studied segregating populations and their parents followed by their ranks as descending for performance and ascending for all stability parameters are presented in Table 6 for SCY and Table 7 for LY. To simplify the presentation and conclusion, the genotypes were classified according to each criterion into three categories, the top 5 genotypes (23.8%) as superior group (SG) and the least 5 genotypes (23.8%) group (LG) performed or stable and the remainder 11 genotypes (52.4 %) as moderate group assigned as MG.

**Table 6. Mean performance and stability parameters for seed cotton yield of F2/F3 segregating cotton populations and parental genotypes over eight experiments during 2019 and 2020 seasons.**

| Genotype | Mean | | $b_i$ 1) | | $S^2d_i$ 2) | | $W_i$ 3) | | RS 4) | | $YS_i$ 5) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Value | R | Value | R | Value | R | Value | R | Value | R | Value | R |
| P1 | 53.7 | 18 | 0.95 ** | 6 | 31.6** | 20 | 206.3** | 20 | 38 | 20 | -1 | 20 |
| P2 | 51.5 | 21 | 0.95** | 7 | 17.2 ** | 18 | 119.6* | 18 | 39 | 21 | -7 | 21 |
| P3 | 54.6 | 11 | 1.04** | 14 | 7.7 ** | 10 | 61.8 ns | 10 | 21 | 12 | 8 | 11 |
| P4 | 53.9 | 16 | 0.89** | 1 | 7.9 ** | 11 | 71.0 ns | 13 | 29 | 15 | 5 | 16 |
| P5 | 56.6 | 3 | 1.05** | 18 | 3.1 ns | 2 | 35.1 ns | 1 | 4 | 1 | 16√ | 3 |
| P6 | 54.6 | 12 | 1.00 ns | 11 | 5.9 ns | 7 | 49.9 ns | 7 | 19 | 8 | 9√ | 10 |
| P1xP2 | 55.8 | 7 | 1.04** | 15 | 3.4 ns | 3 | 35.9 ns | 2 | 9 | 2 | 14√ | 6 |
| P1xP3 | 56.6 | 2 | 1.01 ** | 12 | 6.4 ** | 8 | 52.7 ns | 8 | 10 | 3 | 21√ | 1 |
| P1xP4 | 56.4 | 5 | 1.11** | 20 | 3.6 ns | 4 | 46.3 ns | 6 | 11 | 4 | 14√ | 6 |
| P1xP5 | 54.3 | 14 | 0.98 ** | 9 | 8.5 ** | 13 | 65.7 ns | 11 | 25 | 14 | 7 | 13 |
| P1xP6 | 55.6 | 9 | 0.98** | 10 | 4.5 ns | 6 | 41.7 ns | 4 | 13 | 5 | 6 | 14 |
| P2xP3 | 54.5 | 13 | 1.03 ** | 13 | 35.1 ** | 21 | 225.9** | 21 | 34 | 17 | 8 | 11 |
| P2xP4 | 53.2 | 20 | 0.90** | 2 | 2.6 ns | 1 | 39.1 ns | 3 | 23 | 13 | 1 | 18 |
| P2xP5 | 56.5 | 4 | 1.05** | 17 | 13.3 ** | 15 | 96.2* | 15 | 19 | 8 | 11√ | 8 |
| P2xP6 | 56.4 | 6 | 1.07** | 19 | 8.5 ** | 12 | 68.8 ns | 12 | 18 | 7 | 15√ | 4 |
| P3xP4 | 53.3 | 19 | 0.95** | 5 | 14.1** | 16 | 101.6* | 16 | 35 | 19 | 0 | 19 |
| P3xP5 | 57.2 | 1 | 1.15** | 21 | 22.6 ** | 19 | 170.1** | 19 | 20 | 11 | 18√ | 2 |
| P3xP6 | 54.6 | 10 | 1.04** | 16 | 7.5 ** | 9 | 60.8 ns | 9 | 19 | 8 | 11√ | 8 |
| P4xP5 | 54.0 | 15 | 0.90** | 3 | 10.44 ** | 14 | 85.3 ns | 14 | 29 | 15 | 6 | 14 |
| P4xP6 | 53.8 | 17 | 0.96* | 8 | 14.98 ** | 17 | 105.8* | 17 | 34 | 17 | 4 | 17 |
| P5xP6 | 55.6 | 8 | 0.94** | 4 | 4.19 ns | 5 | 42.2 ns | 5 | 13 | 5 | 15√ | 4 |
| Mean | 54.9 | | | | | | | | | | 8.6 | |

**1) * and **= significant at 5% and 1% of regression coefficient from unity.**
**2) ns = stable genotype/s, * and ** = unstable genotype/s at 5% and 1%, respectively of S2d from zero.**
**3) ns = stable genotype/s, * and ** = unstable genotype/s at 5% and 1%, respectively of Wi**
**4) The lowest RS is the most desirable as stable corresponding with relatively high yield.**
**5)√indicates stable genotypes on basis of yield-stability statistic (YSi).**

**Table 7. Mean performance and stability parameters for lint yield (LY) of the fifteen $F_2/F_3$ segregating cotton populations and six parents over eight experiments during 2019 and 2020 seasons.**

| Genotype | Mean | | $b_i$ 1) | | $S^2d_i$ 2) | | $W_i$ 3) | | RS 4) | | $YS_i$ 5) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Value | R | Value | R | Value | R | Value | R | Value | R | Value | R |
| P1 | 20.9 | 20 | 0.85** | 2 | 4.2** | 20 | 32.5 ns | 19 | 39 | 21 | 1 | 19 |
| P2 | 20.7 | 21 | 0.91** | 5 | 1.6** | 15 | 14.1 ns | 14 | 35 | 20 | -8 | 21 |
| P3 | 22.3 | 8 | 1.10** | 18 | 1.3* | 13 | 12.9 ns | 12 | 21 | 11 | 15 √ | 7 |
| P4 | 21.5 | 16 | 0.86** | 3 | 0.9 ns | 6 | 11.9 ns | 11 | 27 | 15 | -3 | 20 |
| P5 | 23.0 | 3 | 1.11** | 19 | 1.5** | 14 | 14.4 ns | 16 | 19 | 8 | 20 √ | 2 |
| P6 | 23.1 | 2 | 1.18** | 21 | 3.1** | 18 | 27.3 ns | 18 | 20 | 9 | 17 √ | 4 |
| P1xP2 | 22.0 | 12 | 1.02** | 13 | 0.5ns | 5 | 6.7 ns | 3 | 15 | 5 | 9 | 11 |
| P1xP3 | 22.6 | 5 | 1.01ns | 12 | 0.4 ns | 2 | 5.8 ns | 2 | 7 | 1 | 10 √ | 10 |
| P1xP4 | 22.5 | 7 | 1.07** | 15 | 0.9 ns | 7 | 9.5 ns | 5 | 12 | 4 | 16 √ | 6 |
| P1xP5 | 21.7 | 14 | 0.97** | 9 | 1.8** | 16 | 14.3 ns | 15 | 29 | 17 | 7 | 13 |
| P1xP6 | 22.1 | 9 | 1.00ns | 10 | 1.2* | 10 | 10.7 ns | 8 | 17 | 7 | 14 √ | 8 |
| P2xP3 | 21.8 | 13 | 1.01ns | 11 | 5.8** | 21 | 38.2 ns | 21 | 34 | 18 | 8 | 12 |
| P2xP4 | 21.3 | 19 | 0.85** | 1 | 0.5 ns | 4 | 10.0 ns | 6 | 25 | 13 | 2 | 18 |
| P2xP5 | 22.6 | 6 | 1.05** | 14 | 1.2* | 11 | 11.4 ns | 10 | 16 | 6 | 17 √ | 4 |
| P2xP6 | 22.8 | 4 | 1.08** | 16 | 0.4 ns | 3 | 6.9 ns | 4 | 8 | 2 | 19 √ | 3 |
| P3xP4 | 21.3 | 18 | 0.95** | 8 | 1.1 ns | 9 | 10.7 ns | 7 | 25 | 13 | 3 | 17 |
| P3xP5 | 23.1 | 1 | 1.17** | 20 | 4.1** | 19 | 33.0 ns | 20 | 21 | 11 | 22 √ | 1 |
| P3xP6 | 22.0 | 11 | 1.08** | 17 | 1.1ns | 8 | 11.1 ns | 9 | 20 | 9 | 12 √ | 9 |
| P4xP5 | 21.5 | 15 | 0.89** | 4 | 1.3 * | 12 | 12.9 ns | 13 | 27 | 15 | 6 | 14 |
| P4xP6 | 21.4 | 17 | 0.91** | 6 | 2.8** | 17 | 21.2 ns | 17 | 34 | 18 | 4 | 16 |
| P5xP6 | 22.1 | 10 | 0.93** | 7 | 0.2 ns | 1 | 5.5 ns | 1 | 11 | 3 | 5 | 15 |
| Mean | 22.0 | | | | | | | | | | 9.3 | |

**1) * and **= significant at 5% and 1% of regression coefficient from unity.**
**2) ns = stable genotype/s, * and ** = unstable genotype/s at 5% and 1%, respectively of S2d from zero.**
**3) ns = stable genotype/s, * and ** = unstable genotype/s at 5% and 1%, respectively of Wi**
**4) The lowest RS is the most desirable as stable corresponding with relatively high yield.**
**5)√ Stable genotypes on basis of yield- stability statistic (YSi).**

Accordingly, for SCY, P5 (G.90CB.58) is only the parental member of the superior SC yielder group (SSCYG), whereas P1 (G.90) and P2 (G.94) ranked the least performed group (LSCYG) and the remainder three parents (P3, P4, and P6) belonged to the moderate group (MSCYG). P5 (G.90 CB) also only exhibited desirable ranks by all studied parametric or nonparametric stability measures in addition to it may be responsive to favorable environments due to its $b_i$= 1.05**. The G.90 and G.94 two varieties considered as LSCYG, also ranked among the high unstable group (HUSG) according to $S^2d_i$, $W_i$, RS, and $YS_i$ for SCY. Regarding the regression coefficient $b_i$ as a measure of response, three parents (P1, P2, and P4) seemed to be responsive to poor environments due to it recorded significantly lower b than unity, but P3 and P5 may be performed better under favorable conditions. The reminder parent, *i.e.,* Australian (P6) could be performed stable with somewhat reliable SCY as indicated of $YS_i$.

Concerning the $F_2/F_3$ cross combinations of G.90 (P1) with other five parents, three of these populations (P1 with P2, P3, and P4) recorded significantly desirable of the two non-parametric measurements (RS &$YS_i$) which proved proper SCY accompanied stability. This is agreed for SCY with P1 xP3 and P1x P4 (which are considered high yielders) and P1 with P2 and P4 for stability in performance by using $S^2$d (which seemed to be stable). The first three of these five combinations (of P1 with others) recorded significantly higher bi than unity and thus could be used for selections that may be recommended under favor conditions. However, the rest two populations (P1 with P5 and P6) may be useful for extraction selections for poor conditions (mainly late sowing and stressed irrigation regimes). Moreover, the P1xP6 population may be desirable for production relatively high SCY selections with stability as ranked the $5^{th}$.

For the segregating combinations of P2 (G.94) as common parent, only two populations (those with P5 & P6) could be considered for further selections due they are given significantly higher SCY (≈ 56.5 g) than the overall mean (=54.9g) and common parents, *i.e* P2=51.5 g and P6=54.6 g. These two populations showed desirable values of the non-parametric stability criteria, i.e RS and $YS_i$ despite not encouraging ranks of parametric stability statistics. Among the combinations of P3 as a common parent, $P_3xP_5$ (along to $P_1xP_3$ which was previously aforementioned as high yielder) recorded significantly the highest SCY ($1^{st}$ rank) and $YS_i$ ($2^{nd}$ rank) with maybe responsive to good environments (due to $b_i$= 1.15**) though it gives undesirable estimates of parametric stability.

The combinations of $P_4xP_5$ and $P_4xP_6$ are neither proper yielders nor desirable stable by using any used stability measurements. The population of crosses G.9oCB58 (P5) with Australian (P6), showed significantly higher SCY (55.6 g) than overall average (54.9 g) and its Australian parent (54.6 g) comparing to estimated $LSD_{0.05}$ (=0.7) and $LSD_{0.01}$ (=0.9). Moreover, this population recorded among the superior stable group (SSG) of all investigated stability parameters in addition to it seems responsive to poor environments) which may be encourage for producing selections proper to late sowing and water saving irrigation conditions.

For lint yield (LY), P5 (G.90CB.58) and P6 (Australian) are the parental members among of the superior lint yielder group (SLYG), whereas P1 (G.90) and P2 (G.94) ranked among the least lint yielders (LLYG) and the remainder two parents P3 (G.95) and P4 (Karashanky) belonged to the moderate lint yielders (MLYG). Both P5 and P6 two SLYG parents and P3 (G.95, MLYG) recorded significant stabile in performance for LY measured only by yield-stability statistic $YS_i$. This indicates that these three varieties may produce higher LY corresponding with stable in performance. Regarding the regression coefficient $b_i$ as a measure of response, P3, $P_5$, and $P_6$ also may be performed better under favorable conditions. However, P1, P2, and P4 parental genotypes seemed to be responsive to poor environments because they recorded significantly lower $b_i$ than unity coupled with significantly lower LY than the grand mean (22.0 g). It's worth to observe that Karashanky genotype (P4) is the sole parent of insignificant $S^2d_i$ which means stable in LY performance, but it may be considered unstable judging be both nonparametric Kang's parameters (RS &$YS_i$) and vice versa for P3, P5 and P6.

Three of the $F_2/F_3$cross combinations of G.90 (P1) with P2, P3 and P4 recorded significantly higher lint yield than their respective 4 parents and the grand mean of all genotypes (22.0 g), though P1xP3 is only the member of superior group, SLYG (the higher 23.8% group). Three of these populations (P1 with P2, P3 and P4) recorded significantly desirable stability according to non-parametric two measurements (RS &$YS_i$) in addition to insignificant $S^2d_i$ and $W_i$ which an indication of their possessing proper LY accompanied stability. Two of these cross combinations (P1xP2 & P1xP4) recorded significantly positive $b_i$, which indicating their capability to response to favorable conditions.

For the segregating combinations of P2, only two populations with P5 & P6 could be considered for further selection due they are given significantly higher LY than the overall mean (=22.0 g). These two populations showed desirable values of the non-parametric stability criteria, i.e RS and $YS_i$ coupled with significantly $b_i$ than unity. Among the combinations of P3 as a common parent, the cross of P3xP5 significantly recorded the highest LY ($1^{st}$ rank) and $YS_i$ ($1^{st}$ rank) with higher responsive to good environments (bi= 1.17**) though it gives undesirable estimates of parametric stability. None of the cross combinations involved P4 (Karashanky) with other parents showed promising for selecting high LY with desirable stability except the P1xP4.

Concerning the cross combinations involved P5 (G.90CB58) as common parent with other five genotypes, only the population of P2xP5 and P3xP5 exhibited significantly higher LY accompanied by significant $YS_i$ which offered opportunity for simultaneous selection for higher yield and desirable stability. For crosses of P6 (Australian) as common parent, only this with G.94 (P 2) could be effective for producing reliable selections for LY and stable as proved by all used parameters.

The above-mentioned results proved that the studied Egyptian cotton genotypes exhibited variable stability reactions across the investigated environments that differed from the recorded traits. Therefore, these genotypes seemed to possess a variable genetic mechanism that conditions their reaction to climatic factors. This may be valuable for utilizing such collection for improving sustainable Egyptian cotton genotypes production.

Kang (1993) proposed yield stability statistic ($YS_i$), which valid of simultaneous selection for upgrading mean performance and stability. This statistic involves genotype rankings based on Shukla's stability variance $\sigma^2_i$ (Shukla, 1972) and mean performance rankings after a protected LSD adjustment. Thus, the previously mentioned segregating populations may be released as commercial varieties and/or to be incorporated as breeding stocks in the Egyptian cotton breeding programs aiming for producing high-yielding lines. Similar conclusion was reported by Khalifa *et al*. (2010), Dewdar (2013), Said (2016), and Koleva and Dimitrova (2021) when they estimated the stability of cotton genotypes using the method of yield stability statistic ($YS_i$).

**4. Rank correlation among stability statistics and yield**

To clarify the relation among mean performance of SCY and LY and corresponding five parametric and non-parametric stability statistics, the rank correlation coefficients were estimated. The genotypes were ranked for mean yield in descending order, but for all stability parameters in ascending manner. The estimates of rank correlation for SCY and LY are presented in Table 8. The ranks of genotypes for mean performance either SCY or LY over the studied eight environments was highly significantly positively correlated with corresponding $b_i$ and $YS_i$. The ranks of regression coefficients ($b_i$) seemed related significantly positive with those of $YS_i$ for these traits. Also, the $S^2d_i$ stability measure is related significantly positive with ecovalence (Wi), and rank-sum (RS) and the ranks of both latter criteria ($W_i$ & RS) are significantly positively correlated.

It's clear that the ranks of genotypes of mean performance of each SCY and LY are positively related to those of $b_i$ and $YS_i$, whereas those of these two stability measurements are negatively related with RS. Simply RS is the product of assigned ranks for both mean yield (in descending order) and stability variance ($\sigma^2_i$) with ascending manner. Thus, RS is correlated positively with variance dependent two criteria ($S^2d_i$ and $W_i$). However, cultivar possesses higher $YS_i$ than the grand mean of tested cultivars ($\sum YS_i/n$) considered higher yielder coupled with desirable stable in performance.

**Table 8. Rank correlation matrix for stability analysis procedures conducted on fifteen $F_2/F_3$ segregating cotton populations and six parents over eight experiments for seed cotton yield (SCY) and lint yield (LY) during 2019 and 2020 seasons.**

| Parameter | SCY (g/plant) | | | | |
|---|---|---|---|---|---|
| | **Mean** | **bi** | **$S^2$d** | **Wi** | **RS** |
| bi | 0.78** | | | | |
| $S^2$d | -0.32 ns | -0.07 ns | | | |
| Wi | -0.35 ns | -0.10 ns | 0.99** | | |
| RS | -0.83** | -0.55** | 0.77** | 0.80** | |
| YSi | 0.94** | 0.71** | -0.37 ns | -0.40 ns | -0.83** |
| | LY (g/plant) | | | | |
| bi | 0.88** | | | | |
| $S^2$d | -0.08 ns | 0.11 ns | | | |
| Wi | -0.07 ns | 0.08 ns | 0.97** | | |
| RS | -0.72** | -0.53* | 0.70** | 0.73** | |
| YSi | 0.94** | 0.91** | 0.04 ns | 0.03 ns | -0.62** |

**Ns, * and ** indicate insignificant and significant correlation coefficients at 5% and 1%, respectively.**

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# تحليل الثبات لعشائر القطن المصري في الأجيال الإنعزالية المبكرة وآبائها خلال فترات ري ومواعيد زراعة مختلفة

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تم تقييم خمسة عشر عشيرة من القطن المصري في الأجيال الانعزالية الثاني والثالث وآبائها فى موعدى الزراعة المبكر (الاسبوع الاول من ابريل) والمتأخر (الاسبوع الاول من مايو) وفى كل موعد نفذت تجربتين بنظامى الري العادي (كل 14 يوم ) والرى الإجهادى (كل 28 يوم) خلال موسمي 2019 و2020 باجمال ثمان تجارب نفذت في كلية الزراعة جامعة المنيا. و ذلك بهدف استكشاف امكانيات هذه التوافيق الهجينية فى أن تكون مصدرا لانتخاب تراكيب وراثية واعدة انتاجيا ومتكيفة للتغيرات البيئية و المناخية، وتم تقدير ثبات الأداء خلال الثمان بيئات المختبرة باستخدام طريقتي تحليل الانحدار وتحليل المكافأت البيئية الراجعة لكل تركيب وراثي باستخدام ثلاثة من معايير الثبات المعلمية وأثنين من المقاييس اللامعلمية. سجل تحليل التباين المتجمع أن كل من تباينات التراكيب الوراثية و الظروف البيئية وتفاعلاتها كانت عالية المعنوية علي اداء كل الصفات ، وكانت مقادير تباينات البيئات اكبر بخمس اضعاف عن تباينات التراكيب الوراثية. كان الاب الخامس هو الوحيد من الستة اباء المستخدمة الذى أظهر أعلى قيمة لمحصول القطن الزهر و متقدما فى ترتيب ثبات الأداء باستخدام كل تقديرات الثبات، فى حين تشارك الأب السادس مع الأب الخامس فى تفوق قيمة محصول التيلة مع مقدار ثبات المحصول اللامعلمى. أظهرت ثمانية تراكيب وراثية من الخمسة عشر المستخدمة كعشائر انعزالية بالإضافة الى الأبوين الخامس والسادس تفوقا عالى المعنوية فى حاصل القطن الزهر و الشعر على المتوسط العام وعلى متوسطات آبائها المشتركة بالإضافة معنوية معايير ثبات الأداء، مما يدفعنا الى التوصية باستخدامها فى برامج التربية بالانتخاب للحصول على تراكيب وراثية من القطن المصرى متفوقة انتاجيا بالاضافة الى ثباتها وتكيفها مع الظروف السلبية الناتجة عن التغيرات المناخية.