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Selection Response for Improving the Performance of Egyptian Cotton under Late Planting and Soil Moisture Stress†

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Abstract: Twenty-seven F_4 progenies of individual selections and unselected bulks were evaluated in early and late summer plantings either irrigated normally or stressed. The objectives were to elucidate the efficiency direct and indirect individual selection in some Egyptian cotton segregating populations for reliable performance under harsh environmental conditions. The cotton plants of F4 produced higher lint yields under early sowing either normal or stress watering regimes (EN and ES) than those planted under late sowings or combined across all environments. Direct selection is better than indirect selection for improving lint yield and boll weight under normal watering regimes and for seed index and lint index under stress watering regimes either early or late sown. Maximum expected gain for F4 progenies was obtained for lint % trait from indirect selection to ES for the relative to correlated response under practiced under EN environment.

Keywords: Egyptian cotton; *Gossypium barbadense*; Selection gain; Crop resilience; correlated response; Variation

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1. Introduction

Egyptian cotton (Gossypium barbadense L.) is one of the most important strategic national crops in Egypt. Its acreage, in season 2022, was about 337.6 thousand feddans (0.42 ha) [1]. Climate change in the form of raising and fluctuating temperatures with heightened competition for scarce natural resources potentially threatens the sustainability of agricultural production. Cotton appeared to be the most sensitive crop to variation of environmental and agroclimatic conditions [2]. Stressful environmental conditions along with insufficient water irrigation influence the phenology and yielding performance of the Egyptian cotton [3,4]. However, unpredictable climatic fluctuations greatly affect the productivity and resilience of Egyptian cotton varieties and consequently should considered for releasing new varieties [5–7]. Genetic improvement in a crop requires in-depth knowledge of variability along with information of interrelationships among various traits so that an efficient selection strategy can be formulated. High heritability estimates accompanied by a high genetic gain are the most important criteria for direct selection, whereas the correlated response occurred in unselected character/s synergistically forms the basis of indirect selection. Likewise, the theory of correlated response to selection developed by Falconer [8] permits breeding strategies to be evaluated based on the predicted response in the target environment resulting from selection conducted in a selected environment. Thus, the aim of the present investigation is to elucidate the effectiveness of selection under different environmental conditions particularly under unstressed ones to perform reliably under undeveloped cotton that may be resilient to the effects of climate change. The present investigation was conducted to explore the magnitudes of genetic variation of 27 F4 selected progenesis for yield traits under variable environmental conditions and to identify the best selection environment for use in the target environment.

2. Materials and Methods

2.1. Plant Material and Experimental Design

Twenty-seven selected Egyptian cotton progenesis traced back to a diallel cross carried out among six cotton elite genotypes during 2015 [9]. The resulted fifteen F2/F3 segregating populations along with their parents were evaluated under eight trials during 2019 and 2020 seasons [7,10]. In each season, four field trials were conducted using two sowing dates as early (E) and late (L) during April and May, respectively. In each sowing date, two separate trials were carried out, by irrigation each two weeks as normal (N) or each four weeks as stress (S) irrigation (Figure 1). Each trial was conducted as RCBD with three replications with single-ridge plots, each was four meters long and 65 cm wide (2.6 m2). Out of these 15 populations, nine F2's were considered for selecting the best performed individual plant in each replicate. The F4 individual selection progenies along to the corresponding F3 nine bulks were evaluated under field conditions during the 2021 season at the Faculty of Agriculture, Minia University, Egypt. The experimental procedures similarly to previous seasons as early or late sowings and normal or stressed watering regimes were followed except two replications.

A random sample comprised of ten guarded plants from each plot was harvested and the studied traits were recorded for each plant and the averages of lint cotton yield (LY) per plant in grams was calculated. The lint percentage (L%) is the ratio of lint (LY) to seed cotton. Lint index (LI) was the mean weight of lint obtained from 100 seeds in grams. Seed index (SI) was the weight of 100 seeds in grams. The boll weight (BW) was the average weight of five bolls picked at random from each plant.

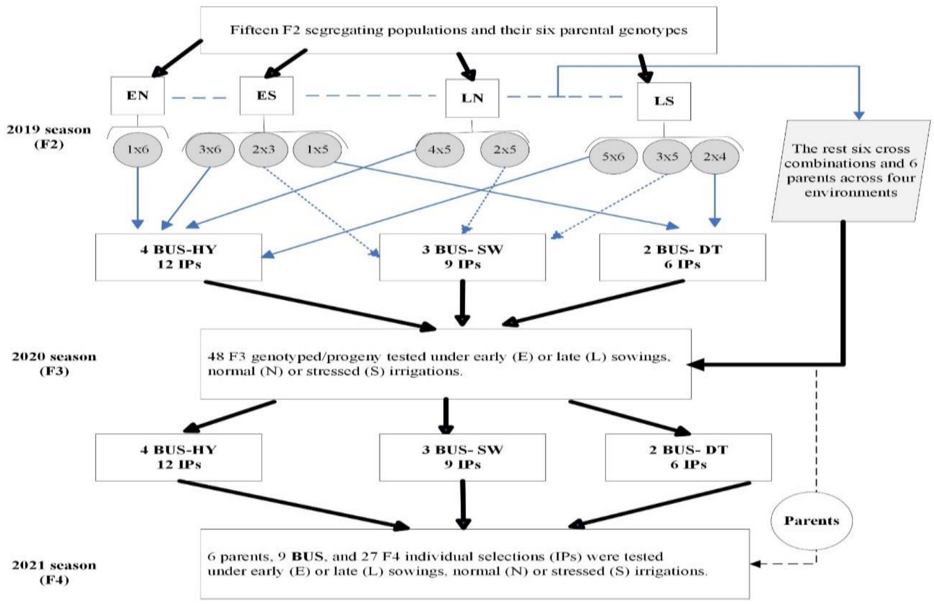

Figure 1. Layout of development population (BUS) and individual selections (IPS) during 2019, 2020 and 2021 seasons (HY=high yield, SW=stepwise, DT= drought tolerance).

2.2. Statistical techniques

The obtained data of each experiment was analyzed as RCBD to explore the differences among cotton genotypes in each sowing date or watering regime trials. Broad sense heritability (h2), genotypic (GCV%) and phenotypic (PCV%) coefficients of variations were calculated according to [11].

Corelated response to selection (CRY) and the ratio of correlated response to direct response (CRY/Ry) were calculated following Falconer [8] as follows:

$$RY = i \times \sqrt{h2y} \times \delta Py \quad (1)$$

$$CRY = i \times \sqrt{h2x} \times \sqrt{h2y} \times rg_{xy} \times \delta Py \quad (2)$$

Where: i= 1.55 is the selection intensity for better 4 individuals (=15.5%), hx and hy are a broad sense heritability of dependent (x) or independent (y) traits or environments, respectively, rg_{xy} is genotypic correlation and δPy is a phenotypic standard deviation of Y.

3. Results and Discussion

3.1. Parameters of varations within given environmental conditions

The mean performance and the parameters of variations of the F4 individual plant selections (IPS) along to unselected F4 bulks (BUS) over each sowing date (E & L), either irrigated normally or stressed (N & S) and over the conducted four trials are presented in Table 1.

The cotton plants of F4 either selected individually (IPS) or unselected bulks (BUS) produced higher lint yields under early sowing either normal or stress watering regimes (EN and ES) than those planted under late sowings or combined across all environments. The mean performance of unselected F4 bulks (BUS) is better for all studied traits under early sowing with normal irrigation (EN) than all other environments. These bulks may be considered the outcome of F3 selections with intrapopulation heterogeneous.

The phenotypic coefficient of variation (PCV%) was moderately higher than the genotypic coefficient of variation (GCV%) for all the traits in both types of cotton selections (IPS and BUS) which suggested that the presence of environmental influences.

The F4 cotton selections (IPS and BUS) showed higher magnitudes of PCV and GCV coupled with higher values of heritability under each of all four trials for LY than other studied traits, proving the presence of remaining variability which may be useful for further selection.

For unselected bulks recorded higher GCV% and PCV% for LY under both stressed environmental sowings than other tabulated traits or individual selections which again proved the usefulness of further selections for lint yield.

On the other hand, the F4 individual plant selections showed lower GCV% and PCV% coupled with low heritability percentages for L% and BW under ES and LN trials than those under EN and LS.

Overall, based on the results for both IPS and BUS, it could be concluded that there is great scope for improvement of lint yield by direct selection. Other presented traits, viz lint % and boll weight were moderately and low variable and thus appear to be amenable for further improvement.

Table 1. Variation parameters of F4 individual progenies (IPS) and unselected bulks (BUS) for some yield traits across the four trials during 2021 season.

Trait	**Env.**	**EN**		**ES**		**LN**		**LS**		**Combined**	
	Type	**IPS**	**BUS**	**IPS**	**BUS**	**IPS**	**BUS**	**IPS**	**BUS**	**IPS**	**BUS**
LY	Mean	25.06	25.68	23.89	22.76	23.10	20.92	20.65	20.63	23.18	22.67
	Min	19.07	23.62	17.30	20.10	17.50	19.50	16.00	15.90	16.00	15.60
	Max	31.13	27.55	27.90	30.10	29.00	23.60	27.80	26.40	31.13	30.10
	GCV%	9.7	6.9	8.7	17.8	13.0	5.8	10.5	23.4	3.1	2.7
	PCV%	12.3	8.6	11.1	18.8	14.4	7.5	15.0	23.8	10.9	8.3
	$h^2_{b.s}$%	0.623	0.647	0.618	0.892	0.817	0.594	0.487	0.972	0.079	0.108
L%	Mean	40.37	40.44	40.32	40.45	40.38	40.46	40.93	40.92	40.55	40.57
	Min	38.37	39.43	38.27	39.59	39.37	39.48	39.43	40.44	38.37	39.43

	Max	42.07	41.87	41.46	41.57	41.37	41.51	42.78	41.81	42.78	41.87
	GCV%	1.7	2.4	1.0	2.3	0.9	2.2	1.5	1.1	1.5	0.6
	PCV%	2.8	2.7	2.5	2.7	1.9	2.3	2.1	1.7	2.1	1.4
	$h^2_{b.s}$%	0.352	0.783	0.156	0.752	0.212	0.912	0.562	0.483	0.539	0.181
BW	Mean	2.63	2.70	2.42	2.45	2.88	2.86	2.61	2.55	2.63	2.64
	Min	2.36	2.37	2.20	2.22	2.66	2.68	2.42	2.44	2.20	2.22
	Max	2.86	2.81	2.86	2.84	3.18	3.08	2.78	2.82	3.18	3.08
	GCV%	4.6	6.4	4.2	10.7	3.0	6.1	2.3	5.1	0.7	0.01
	PCV%	6.3	7.2	6.9	11.6	5.4	6.8	4.2	6.3	3.9	4.8
	$h^2_{b.s}$%	0.520	0.782	0.369	0.853	0.308	0.794	0.308	0.671	0.035	0.001

3.2. Expected genetic gain from selection.

Expected genetic advance from selection for cotton yield attributes under early (E) or late (L) sowing dates, normal (N) or stressed (S) irrigation regimes for direct and indirect selection for the selection under target environment using 15.0 % selection intensity are presented in Table 2.

Genetic gain from direct selection is higher under normally irrigated environments planted either early or late than those of stressed irrigated ones for LY and BW. However, higher expected gain could be observed under stressed watering regimes (ES and LS) than normal ones (EN and LN) for SI and LI. This may be due to the higher magnitudes estimated heritability for these traits observed under the respective environments. Thus, based on the present results, it could be recommended using direct selection for improving LY and BW traits under normal irrigation, but for upgrading cotton seed index (SI) and int index (LI), it seems to be carried out selection under stressed irrigation of those early or late sowings. These results agree with the opinion of selection under the environment of production. However, [12] suggested selection under a favorable environment, and some believe in selection under typical drought conditions [13].

The approach of correlated response to selection developed by [8] and reviewed by [14] helps breeding strategies to be evaluated based on the predicted response in the target environment resulting from selection conducted in a selection environment. However, [12] concluded that the heritability of yield and the genetic correlation between the yield in the selection and target environments could be used to identify the best environment that would optimize correlated response.

The lint % (L%) under EN and ES, SI and LI under LN, recorded higher ratios of CRy/Ry than unity, indicated that the indirect selection seems to be more effective than direct one (Table 2). Thus, it may be concluded that for these traits, further selection among F4 progenies under respective environments, under EN, ES, or LN environment may be reflected on upgrading the performance of cotton selections under other environmental conditions. Maximum expected gain for F4 progenies was obtained for L% trait (CRy/Ry= 2.36) from indirect selection to ES for the relative to correlated response under practiced under EN environment. Other, obtained ratios of CRy/Ry proved that for selection improvement of other cotton traits, it's beneficial to carried out under target environment/s rather than indirect selection.

Table 2. The expected gain from direct selection (Ry) on each environment, the correlated response (CRy) expected to occur at the other one and the ratio of CRy/Ry responses of selected F4 progenies under stress (S) and normal (N) irrigation of early (E) and Late (L) sowing of 2021 season.

Traits	Irrigation regimes	Early sowing (E)			Late sowing (L)		
		R_y	CR_y	CR_y/R_y	R_y	CR_y	CR_y/R_y
LY	S	2.54	0.38	0.15	2.34	0.00	0.00
	N	2.97	0.44	0.15	4.21	0.00	0.00
L%	S	0.25	0.59	2.36	0.73	0.13	0.18

	N	0.62	0.66	1.06	0.25	0.12	0.48
SI	S	0.34	0.00	0.00	0.68	0.47	0.69
	N	0.11	0.00	0.00	0.37	0.40	1.08
LI	S	0.34	0.11	0.32	0.43	0.27	0.63
	N	0.22	0.13	0.59	0.27	0.27	1.00
BW	S	0.10	0.00	0.00	0.05	0.00	0.00
	N	0.13	0.00	0.00	0.07	0.00	0.00

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