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Proceeding Paper

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, either irrigated normally or stressed, were evaluated in early and late summer plantings. The objectives of this study were to elucidate the efficiency of direct and indirect individual selection in some Egyptian cotton segregating populations for reliable performance under harsh environmental conditions. The cotton plants of F_4 produced higher lint yields under early sowing with either normal or stressed watering regimes (EN and ES) than those that were planted under late sowings or combined across all environments. Direct selection is better than indirect selection to improve the lint yield and boll weight under normal watering regimes and for the seed index and lint index under stressed watering regimes with either early or late sowing. The maximum relative expected correlated response to direct selection gain was obtained for the L% trait under ES.

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 the season of 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 variations in environmental and agroclimatic conditions [2]. Stressful environmental conditions along with insufficient water irrigation influence the phenology and yielding performance of Egyptian cotton [3,4]. However, unpredictable climatic fluctuations greatly affect the productivity and resilience of Egyptian cotton varieties and, consequently, they should be considered for releasing new varieties [5–7]. Genetic improvement in a crop requires in-depth knowledge of the variability along with information about the 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 occurring 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, it is crucial 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 F_4 selected progenies 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 progenies traced back to a diallel cross were carried out among six cotton elite genotypes during 2015 [9]. The resulting fifteen F_2/F_3 segregating populations along with their parents were evaluated under eight trials during the 2019 and 2020 seasons [7,10]. In each season, four field trials were conducted using two sowing dates denoted as early (E) and late (L) during April and May, respectively. In each sowing date, two separate trials were carried out: irrigation every two weeks, which was considered normal (N), or irrigation every four weeks, which was considered stress (S) irrigation (Figure 1). Each trial was conducted as RCBD with three replications with single-ridge plots; each plot was four meters long and 65 cm wide (2.6 m^2). Out of these 15 populations, 9 F_2s were considered for selecting the best performed individual plant in each replicate. The F_4 individually selected progenies along with the nine corresponding F_3 bulks were evaluated under field conditions during the 2021 season at the Faculty of Agriculture, Minia University, Egypt. The experimental procedures, similar to the previous seasons, were denoted as early or late sowings, and normal or stressed watering regimes were followed, except for two replications.

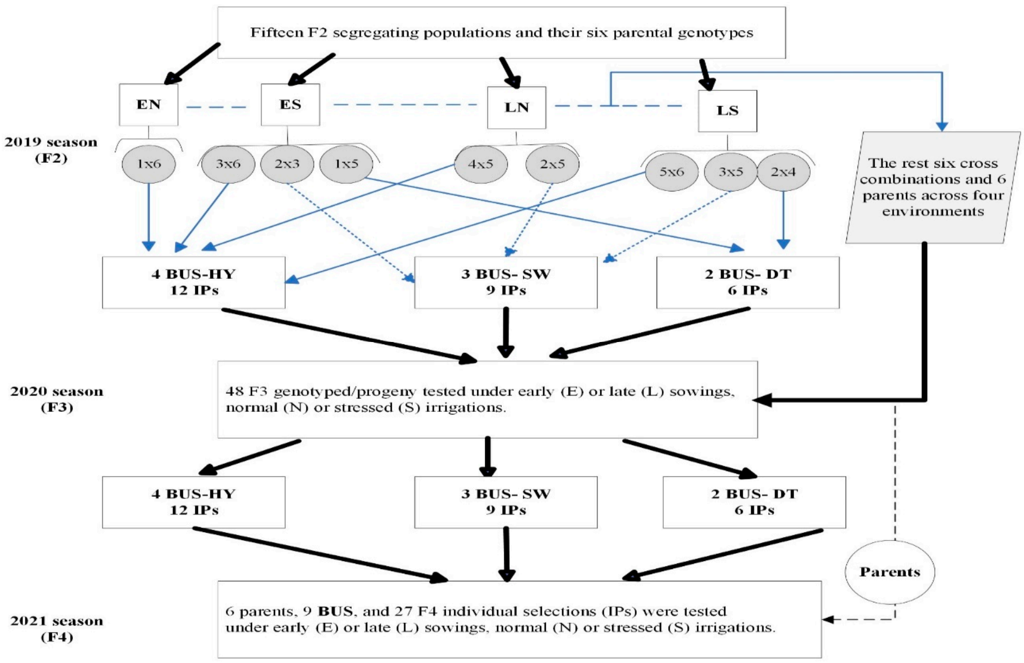

Figure 1. Layout of development population (BUS) and individual selections (IPS) during 2019, 2020, and 2021 seasons (HY = high yield, SW = stepwise, DT = drought tolerance).

A random sample comprising ten guarded plants from each plot was harvested, the studied traits were recorded for each plant, and the averages of the lint cotton yield (LY) per plant was calculated in grams. 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.

2.2. Statistical Techniques

The obtained data from each experiment were analyzed as RCBD to explore the differences among the cotton genotypes in each sowing date or watering regime trial. Broad sense heritability (h^2) and genotypic (GCV%) and phenotypic (PCV%) coefficients of variations were calculated according to [11].

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

$$R_Y = i \times \sqrt{h^2 y} \times \delta Py \tag{1}$$

$$CR_Y = i \times \sqrt{h^2 x} \times \sqrt{h^2 y} \times rg_{xy} \times \delta Py \tag{2}$$

where i = 1.55 is the selection intensity for the better 4 individuals (=14.8%); h_x and h_y are a broad sense heritability of dependent (x) or independent (y) traits, respectively; rg_{xy} is the genotypic correlation; and δPy is a phenotypic standard deviation of Y.

3. Results and Discussion

3.1. Parameters of Variations within Given Environmental Conditions

The mean performance and the parameters of variations of the F_4 individual plant selections (IPS) along with the unselected F_4 bulks (BUS) over each sowing date (E and L), either irrigated normally or under stressed conditions (N and S) and over the conducted four trials, are presented in Table 1.

Table 1. Variation parameters of F_4 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

The cotton plants of F_4 that were either selected individually (IPS) or the unselected bulks (BUS) produced higher lint yields under early sowing with either normal or stressed watering regimes (EN and ES) than those that were planted under late sowings or combined across all environments. The mean performance of the unselected F_4 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 F_3 selections with intrapopulation heterogeneous.

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

The F_4 cotton selections (IPS and BUS) showed higher magnitudes of PCV and GCV coupled with higher values of heritability under each of the four trials for the LY than the other studied traits, proving the presence of remaining variability, which may be useful for further selection.

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

On the other hand, the F_4 individual plant selections showed lower GCV% and PCV% values coupled with low heritability percentages for L% and BW under the ES and LN trials than those under EN and LS.

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

3.2. Expected Genetic Gain from Selection

The expected genetic advances from the selection for cotton yield attributes under early (E) or late (L) sowing dates and under normal (N) or stressed (S) irrigation regimes for direct and indirect selection under a target environment using a 14.8% selection intensity are presented in Table 2.

Table 2. The expected gain from direct selection (Ry) in each environment, the correlated response (CR_y) expected to occur at the other one, and the ratio of CR_y/R_y responses of selected F_4 progenies under stress (S) and normal (N) irrigations with early (E) and late (L) sowing in the 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

The genetic gain from direct selection is higher under normally irrigated environments with either early or late planting than those under stressed irrigated environments for LY and BW. However, a 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 of estimated heritability for these traits that were observed under the respective environments. Thus, based on the present results, it could be recommended to use direct selection to improve the LY and BW traits under normal irrigation, but to upgrade the cotton seed index (SI) and int index (LI), it seems that selection needs to be carried out under stressed irrigation conditions with early or late sowings. These results agree with the opinion of selection under the environment of production. However, ref. [12] suggested selection under a favorable environment, and some believe in selection under typical drought conditions [13].

The approach of a correlated response to selection developed by the author of [8] and reviewed by the author of [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, the authors of [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 a correlated response.

The lint % (L%) under EN and ES, and the SI and LI under LN, recorded higher ratios of CR_y/R_y than unity, which indicates that an indirect selection seems to be more effective than a direct one (Table 2). Thus, it may be concluded that for these traits, further selection among F_4 progenies under respective environments, specifically under EN, ES, or LN environments, may be reflected in the upgrading of the performance of cotton selections under other environmental conditions. The maximum relative expected gain of correlated response to direct selection gain was obtained for the L% trait (CR_y/R_y = 2.36) under ES. The other obtained ratios of CR_y/R_y proved that for the selection improvement of the other cotton traits, it is beneficial for direct selection to be carried out under target environment/s rather than indirect selection.

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