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USING SELECTION INDEX FOR IMPROVING SOME ECONOMIC TRAITS IN COTTON (*G. barbadense* L.)

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ABSTRACT

The present study was conducted during three growing seasons of 2016, 2017 and 2018 at Sakha Agricultural Research Station. Three generations F_2, F_3 and F_4 of the intra specific cotton (Gosssypium barbadense L.) cross Giza 86 x Pima S6 were used to study the selection index and to compare it with direct and indirect selections to detect superior families, in addition to estimate correlated response to the selection also to predict and realize genetic advances from different selection procedures. A comparison of mean performance for different traits among the three generations F_2, F_3 and F_4 revealed increase in mean values for all traits with advanced generation's fromF_2 to F_4, except micronaire reading (desirable values). PCV and GCV were generally larger in magnitude for all studied traits in F_2 generation as compared with advanced generations F_3 and F_4. High heritability values over 50% were recorded for most studied traits over generations, indicating high magnitude of genetic variability and gave possible success in selection in early generations. Significant desirable correlations between boll weight and each of seeds /boll, seed index and lint /seed were existed over the three generations. Predicted and realized genetic advances from different selection procedures revealed that ten out of eleven selection indices were more efficient than direct selection for improvement of lint yield in F_2 population. The highest predicted genetic gain from F_2 generation for lint yield/plant was observed when selecting for lint yield/plant with bolls/plant (I_{W1}) followed by selecting for lint yield/plant with lint/seed also lint/plant with boll/plant and selection index in involving lint yield/plant with seeds/bolls. The highest actual genetic gains from F_3 generation for lint yield/plant occurred when selecting directly for lint yield/plant. However the indices I_{W23} (Selection index involving lint yield/plant, seeds/boll and lint/seed) followed by I_{W123} and IW_3 (Selection index involving lint yield/plant, bolls/plant, seeds/boll and lint/seed and selection index involving lint yield/plant and lint/seed) were superior to all selection procedures in amount of actual gain and most indices showed high discrepancy between predicted and actual genetic gain as lint yield/plant. Maximum predicted and actual genetic advance from F_3 and F_4 generation for lint yield/plant were achieved when selecting for lint yield/plant and bolls/plant followed by selection indices containing lint yield/plant, boll/plant, seed/boll and lint/seed as well as selecting for bolls/plant and lint/seed. Direct selection for lint yield/plant and selection index involving lint yield/plant, seeds/boll and lint/seed gave high values of realized advance for bolls/plant, seeds/boll and lint/seed (selected traits) and most yield traits. All selected families exceeded better parent and point start of F_2 means, however some of these families surpassed F_3 families mean for yield traits as well as fiber quality traits. The breeder may utilize such selected families in breeding programs aiming to improve yield and quality.

Key words: ***Genetic advance, Selection procedures, Cotton, Selection index.***

INTRODUCTION

The main objective for a cotton breeder is to evolve high yielding varieties with acceptable fiber quality. Most economic traits such as yield and yield components are known to be complex traits and thus impeded by several factors such as highly affected by environmental factors, polygenic nature and low heritability of a trait, linkage and non-additive effects. Thus, direct selection for yield is not expected to be effective. Therefore, breeder avoids selection for yield and prefers to select for its components individually (El-Mansy 2015), when single trait selection is practiced and the correlation of that trait with other is high and unfavorable, undesirable correlated response may occur for those traits not being considered in selection criteria (Bos and Caligari 2007, Ramadan *et al* 2014 and Abd El Aty*et al* 2017). In this case, multiple trait selection becomes indispensable. Reliability and simplicity are the main prerequisites for the use of a selection index in cotton improvement program.

The simultaneous selection of traits, which can be performed effectively by use of selection index, increases the chances for the success of breeding programs (Costa *et al* 2008 and Muhe 2011), which is multiple regression of genotypic values on phenotypic values of several traits, and are generally used to discriminate among selection units by taking into account both of the genetic and statistical structure of the population from which the genotype originated as well as the economic importance of the traits. Thus, when evaluating only those individuals it is predicted to have progeny of superior economic value to be reproduced (Jesus *et al* 2006).

The use of selection index is superior in improving complex traits. Furthermore, selection index aimed to determine the most valuable genotypes as well as the most suitable combination of traits with the extension of indirectly the yield in different plants (El-Lawendey *et al* 2011).

Reviewing literature indicated that most studies of plant selection frequently have focused on single trait or multiple-trait selection without considering the interrelationship, heritability and the weight of traits and less effort has been devoted to index based selection. Some comparisons of the indices with direct selection allow the conclusion that the use of indices as selection criteria achieved relatively superior results. Several researchers confirmed the efficacy of selection index for improving yield and its components in cotton (El-Lawendey *et al* 2008, El-Mansy 2009, El-Lawendey and El-Dahan 2012, El-Mansy 2015 and Abd El Aty *et al* (2017).Thus, the objectives of the present study were to construct the Simith-Hazel index model of selection index and compare it with direct and indirect selection to enhance selection efficiency of superior families and to estimate correlated response to selection.

MATERIALS AND METHODS

The present study was conducted during three growing seasons of 2016, 2017 and 2018 at Sakha Agricultural Research Station. The genetic materials used in this study were produced from the intra specific cotton (*Gosssypium barbadense* L.) cross Giza 86 x Pima S6. The F_2 generation with the original parents was grown in no replicated row with 4.0 m length, 70 cm width and 40 cm hill space. One plant was left per hill at thinning time and self-pollination was practiced for all F_2 plants. At the end of season selfed as well as open pollinated bolls were ginned from 216 selected F_2 guarded plants separately. Observations were recorded on yield and its components and fiber quality traits; boll weight in g (BW), seed cotton yield/plant in g (SCY), lint yield/plant (LY), lint percentage (LP%), bolls/plant, seeds/plant, seed index (SI), lint index (LI), micronaire reading, fiber strength as Pressely index (Fs) and fiber length (FL).

Using 5% selection intensity with eleven selection indices and four direct selections, 49 F_2 plants were selected on the basis of their performance; the plants having the highest performance in each procedure were saved.

In 2017 season, the F_3 progenies were evaluated with the original parents in a randomized complete blocks design with three replicates. Experimental plot consisted of one row as carried out in 2016. The different selection procedures includes pedigree selection for each selected traits and classical selection index involved all studied traits were applied. Superior progeny of each selection procedure was selected using 5% selection intensity. This gave a total of 12 selected families.

In 2018 season, selfed seeds of 12 selected families were evaluated with the original parents, same like in 2017. The ordinary practices of cotton cultivation were applied. Data were recorded on 5 guarded plants basis for each entry in F_3 and F_4 families for lint yield/plant, seed cotton yield/plant, boll weight, lint percentage, lint/seed, seed index, bolls/plant, seeds/boll, micronaire reading, fiber strength and fiber length.

Statistical procedure

The phenotypic (PCV) and genotypic (GCV) coefficients of variation were estimated according to Kearsy and Pooni (1996). Also, heritability in broad sense was calculated as follows,

$$h_b^2 \text{ (in } F_2 \text{ generation)} = \frac{VF_2 - (VP1 + VP_2)/2}{VF_2} \times 100$$

$$h_b^2 \text{ (in } F_3 \text{ and } F_4 \text{ generation)} = \frac{\sigma^2 g}{\sigma^2 p} \times 100 \text{ (Walker 1960)}$$

Where:

VF_2 = the phenotypic variance of the F_2 generation.

VP_1, VP_2= the variance of the first and second parents.

$\sigma^2 g$ = the genotypic variance of the F_3 and F_4 generations.

$\sigma^2 p$ = the phenotypic variance of the F_3 and F_4 generations.

Genotypic correlation coefficients between studied traits were also computed in three generations according to Falconer and Mackey (1996).

The genotypic correlation (r_{gij}) = $\sigma 2_{gij} / \sqrt{\sigma^2_{gi} \text{ x } \sigma^2_{gj}}$

Where,

σ^2_{pij}, σ^2_{pi} and σ^2_{pj} are the phenotypic covariance between i and j traits and phenotypic variance for i and j traits.

σ^2_{gij}, σ^2_{gi} and σ^2_{gj} are the genotypic covariance between i and j traits and genotypic variance for i and j traits.

The expected gain through direct selection (SGx) and indirect (SGy(x)) were calculated as follow:

$SGx = i\ .\sigma g_x\ .h_b x$

$SGY(x) = i\ .\sigma g_y\ .h_b x\ .rg(yx)$ (Bos and Caligari, 2007)

Where:

i is selection intensity obtained considering a selection of 5% among progenies.

x = Standard deviation of the genotypic variance of trait x.

y = Standard deviation of the genotypic variance of trait y.

$h_{b.x}$ = Square root of heritability in broad sense.

r.g (xy) = is the genotypic correlation between trait x and trait y.

The relative importance or economic values was calculated according to Walker (1960). Classical selection index (Smith-Hazel) was calculated according to Smith (1936) and Hazel (1943).

$(b) = (P)^{-1}. (G).(a)$

Where:

b = vector of relative index coefficients.

(P^{-1}) = inverse of the phenotypic variance – covariance matrix.
(G) = Genotypic variance – covariance matrix.
(a) = vector of relative economic values on the bais of equally important = 1 for all traits.

Predicted improvement in lint yield for selecting 5% of the families on the basis of an index was calculated from the general formula, SGi = $1bG/(vi)^{1/2}$.

Where:
SGi = predicted gain from selection.
i = selection intensity.
bi = is the index weight for the traits considering in an index.
Gi = is the row of genetic matrix.
(vi) = is the index variance.

The predicted response in any selected and unselected traits was also computed according to Falconar (1989) as follows: $GS_k = i.\ \sigma g_{ki}/(\sigma i)^{0.5}$

Where,
i = is the selection differential in standard units.
σg_{ki} = is the genotypic covariance of k trait and the index.
σi = is the variance of the index.

The actual gains were calculated as deviation of generation mean for each trait from procedure mean of the trait.

All these computation were performed by using SPSS (1995) and Minitab Computer Procedures.

RESULTS AND DISCUSSION

Success in cotton crop improvement program depends on the amount of genetic variability and its utilization. In population improvement it is important to determine the extent of genetic variation for traits to be improved. The choice of selection procedures for genetic improvement of cotton is largely conditioned by the type and relative amount of genetic variance in the population, while the gain from selection in a population depends on genetic variability within a population for given trait, heritability and selection intensity (Falconor 1989).

Segregating populations with high mean performance were relatively effective in identifying the superior recombinants. A comparison of mean performance for different traits among the three generations F_2, F_3 and F_4 (Table1).

Table 1. Variance components and genetic parameters estimated of F_2, F_3 and F_4 populations of the cotton cross (Giza 86 x Pima S6).

Traits		B.W.	S.C.Y./P	L.C.Y.	LP%	B/P	S/B
Mean	F_2	3.000	63.490	23.370	36.950	21.410	17.440
	F_3	3.370	86.270	32.780	38.000	25.710	20.280
	F_4	3.480	90.680	35.450	39.170	26.370	19.830
SE Mean	F_2	0.028	1.670	0.608	0.144	0.577	0.142
	F_3	0.170	4.430	1.600	0.680	1.870	0.870
	F_4	0.150	4.300	1.770	0.550	1.310	1.060
Minimum	F_2	1.900	21.300	8.200	32.400	7.500	14.400
	F_3	2.700	31.000	10.900	33.600	11.100	16.200
	F_4	2.900	56.400	21.900	36.600	15.400	15.500
Maximum	F_2	4.000	179.000	64.300	43.300	55.900	24.800
	F_3	4.400	157.900	58.000	42.300	52.600	24.600
	F_4	4.000	131.600	49.100	42.400	41.200	24.800
VP	F_2	0.163	601.000	79.818	4.499	71.921	4.333
	F_3	0.123	502.538	72.169	2.762	44.959	3.049
	F_4	0.098	488.066	68.557	2.414	55.217	7.437
VG	F_2	0.120	571.512	74.270	3.273	69.252	3.412
	F_3	0.093	482.917	69.601	2.302	41.471	2.288
	F_4	0.076	469.616	65.408	2.108	53.511	6.321
VE	F_2	0.043	29.493	5.548	1.226	2.669	0.921
	F_3	0.030	19.620	2.568	0.460	3.488	0.761
	F_4	0.022	18.450	3.148	0.305	1.706	1.116
H2b.s.%	F_2	73.810	95.090	93.050	72.740	96.290	78.750
	F_3	75.570	96.100	96.440	83.350	92.240	75.030
	F_4	77.280	96.220	95.410	87.350	96.910	85.000
PCV%	F_2	13.460	38.610	38.230	5.740	39.610	11.940
	F_3	10.410	25.990	25.920	4.370	26.080	8.610
	F_4	9.000	24.360	23.360	3.970	28.180	13.750
GCV%	F_2	11.570	37.650	36.880	4.900	38.870	10.590
	F_3	9.050	25.470	25.450	3.990	25.050	7.460
	F_4	7.910	23.900	22.820	3.710	27.740	12.680

Table 1. Cont.

Traits		S.I.	L/S	Mic.	F.S.	U.R.%	F.L.mm
Mean	F_2	9.620	0.057	4.310	9.530	83.620	31.680
	F_3	11.800	0.072	4.140	10.260	87.090	32.540
	F_4	11.610	0.075	3.908	10.522		32.842
SE Mean	F_2	0.083	0.001	0.021	0.029	0.087	0.088
	F_3	0.520	0.003	0.150	0.430	1.370	0.740
	F_4	0.260	0.003	0.154	0.262		0.484
Minimum	F_2	6.500	0.035	3.500	8.200	80.100	28.200
	F_3	9.300	0.054	3.400	8.900	82.000	29.000
	F_4	9.900	0.063	3.400	10.000		30.900
Maximum	F_2	13.100	0.088	5.200	10.700	87.200	34.700
	F_3	14.200	0.099	4.800	11.500	90.900	35.500
	F_4	12.700	0.092	4.400	11.800		35.200
VP	F_2	1.477	0.000	0.093	0.185	1.653	1.690
	F_3	1.077	0.000	0.122	0.338	3.141	1.871
	F_4	0.501	0.000	0.087	0.250		1.047
VG	F_2	1.212	0.000	0.067	0.119	0.855	0.796
	F_3	0.809	0.000	0.097	0.149	1.263	1.317
	F_4	0.433	0.000	0.063	0.181		0.813
VE	F_2	0.265	0.000	0.025	0.066	0.799	0.894
	F_3	0.268	0.000	0.025	0.189	1.879	0.554
	F_4	0.069	0.000	0.024	0.069		0.234
H2b.s.%	F_2	82.080	74.440	72.623	64.198	51.704	47.094
	F_3	75.130	85.710	79.910	44.020	40.200	70.380
	F_4	86.330	80.810	72.800	72.530		77.660
PCV%	F_2	12.630	16.760	7.060	4.511	1.538	4.103
	F_3	8.790	11.550	8.430	5.670	2.030	4.200
	F_4	6.100	9.390	7.540	4.750		3.120
GCV%	F_2	11.440	14.460	6.017	3.614	1.106	2.815
	F_3	7.620	10.690	7.540	3.760	1.290	3.530
	F_4	5.660	8.440	6.430	4.050		2.750

BW= Boll weight, SCY/P= Seed cotton yield/plant, LCY/P= Lint cotton yield/plant, LP= Lint percentage, SI= Seed index, L/S= Lint/seed, S/B= Seeds/boll, B/P= Bolls/plant, FL= Fiber length, FS= Fiber strength, MIC= Micronaire reading and UI= Univormity index

The data revealed increase in mean values for all traits with advanced generations from F_2 to F_4 except micronaire reading (desirable values). This shifting in mean values in desirable direction could largely be attributed to the predominance of additive and additive x additive type of gene action and also due to the possible accumulation of favorable alleles as a result of selection procedures adopted in this study.

Similar results were reported by El-Lawendy and El-Dahan (2012) and El-Mansy (2015). The range, an index of variability, was comparatively wider in F_2 generation as compared with the later generations F3 and F_4 for all studied traits. On the other side, most traits showed reduced variability in F_4 generation. At the same time, the lower limits of range were lower in F_2 generation for all studied traits, leading to a wider spectrum of variability. However in advanced generations (F_3 and F_4) the lower limits of range were relatively high and the upper limits were also relatively low, this due to shifting in variability and increased of desirable alleles as a result of selection procedures. The same trend was reported by El-Lawendy *et al* (2011), Ramdan *et al* (2014) and Soliman (2018).

The estimates of genetic variation make the task of breeder easy, so as to make effective selection. The data presented in Table (1) revealed that the PCV and GCV were generally larger in magnitude for all studied traits in F_2 generation as compared with advanced generations F_3 and $F_{4,}$ indicating the magnitude of the genetic variability persisting in this material was sufficient for providing rather substantial amount of improvement through selection of superior progenies. At the same time, the PCV was higher than GCV for all studied traits and in most cases high discrepancy between PCV and GCV were observed in three generations, which reflected high genetic effectes. These results indicated the feasibility of selection for these traits. Similar results were obtained by Ramadan *et al* (2014), El-Mansy (2015) and Abdel Aty *et al* (2017). The reduction in PCV and GCV values in F_3 and F_4 generations may due to reduction in genetic variability and heterozygosity as a result of using different selection procedures which exhausted a major part of variability. These results are in agreement with Soliman and El-Lawendy (2008), El-Lawendy *et al* (2011) and Vinodhana *et al* (2013).

Heritability plays a productive role in breeding expressing the reliability of phenotype as a guide to its breeding value. Heritability values are useful in predicting the expected progress to be achieved through the process of selection. While genetic coefficient of variation along with heritability estimates provide a reliable estimate of the amount of genetic advance to be expected through phenotypic selection (Eranda *et al* 2014). Data presented in Table (1) revealed that there was a wide range of genotypicand phenotypic variances among the traits. High heritability values over 50% were estimated for most studied traits over generations, indicating high magnitude of genetic variability and gave possible success in selection in early generations. On the other side, some traits recorded low heritability value due to reduction in genetic variation; hence the reduction in heritability observed could be due to complex nature of traits and the influence of genotypic by environment interaction (Ahmed *et al* 2006). Some traits showed change in heritability towards higher values in F_3 and F_4 generations; this is due to increased portion of genetic variance to total phenotypic variance, which is due to cryptic genetic changes that have been brought about two cycles of selection. Improvement of heritability values for these traits is of particular interest for breeder as it enhances the scope for improved selection response for such traits. However a great part of traits showed decreased heritability values in broad sense in advanced generations, this probably due to application of several selection procedures which exhausted genetic variability especially the portion of non-additive and lead to more homogeneity in the population. Similar findings were reported by El-Lawendy *et al* (2011) and Abou El-Yazied *et al* (2014).

It is interesting to mention that higher heritability estimates in broad sense did not necessarily provide higher value of genetic advance hence heritability alone provides no indication for amount of genetic progress that could be achieved through selection. However, genetic coefficient of variation along with heritability provides a reliable estimate of the amount of genetic advance to be expected through phenotypic selection (Eranda *et al* 2014). Since plant breeders must be concerned with the total array of economic traits, thus the correlation analysis provides a good index to predict the corresponding changes which occur in one trait at the expense of the proportionate change in the other. Results of genotypic correlation coefficients among the traits through the three generations are presented in Table (2). desirable correlations between boll weight and each of seed/boll, seed index and lint /seedwere existed over the three generations. Makhdoom *et al* (2010) reported that boll weight is the key independent yield components and play prime role in managing seed cotton yield.

Table 2. Genotypic correlation coefficients among the studied traits in F_2, F_3 and F_4 generations of the cross Giza 86 x Pima S6.

	Traits	B.W.	S.C.Y./P	L.C.Y.	LP%	B/P	S/B	S.I.	L / S	Mic.	F.S.	U.R.%
F_2		0.117										
F_3	S.C.Y./P	0.261										
F_4		0.352*										
F_2		0.099	0.993*									
F_3	L.C.Y.	0.279	0.989*									
F_4		-0.339*	0.987*									
F_2		-0.19	-0.256*	-0.155								
F_3	LP%	0.077	-0.016	0.126								
F_4		0.153	-0.268	-0.114								
F_2		-0.216*	0.933*	0.931*	-0.197							
F_3	B/P	-0.087	0.936*	0.916*	-0.058							
F_4		-0.572*	0.966*	0.949*	-0.28							
F_2		0.503*	0.178	0.114	-0.544*	0.024						
F_3	S/B	0.648*	0.357*	0.335*	-0.146	0.134						
F_4		0.557*	-0.780*	-0.814*	-0.032	-0.812*						
F_2		0.651*	-0.071	-0.07	-0.025	-0.269*	-0.048					
F_3	S.I.	0.934*	0.269	0.286*	0.098	-0.065	0.680*					
F_4		0.146	0.455*	0.482*	-0.009	0.331*	-0.577*					
F_2		0.423*	-0.195	-0.138	0.537*	-0.323*	-0.341*	0.801*				
F_3	L / S	0.736*	0.19	0.290*	0.683*	-0.082	0.404*	0.791*				
F_4		0.193	0.121	0.254	0.745*	0.034	-0.422*	0.658*				
F_2		0.187	0.076	0.116	0.36	0.021	0.15	0.026	0.207			
F_3	Mic.	0.03	0.102	0.102	0.006	0.086	-0.144	-0.003	0.004			
F_4		0.125	0.409*	0.392*	-0.176	0.332*	-0.245	0.690*	0.338*			
F_2		-0.326*	-0.196	-0.235	-0.286*	-0.088	-0.351*	-0.176	-0.294*	0.652*		
F_3	F.S.	-0.052	0.084	0.089	0.033	0.113	0.048	-0.01	0.01	-0.173		
F_4		0.248	-0.445*	-0.397*	0.463*	-0.416*	0.416*	-0.457*	0.043	-0.360*		
F_2		-0.003	0.154	0.139	-0.113	0.158	-0.390*	0.137	0.043	0.123	0.225	
F_3	U.R.%	-0.11	0.095	0.128	0.239	0.133	-0.081	-0.004	0.139	-0.264*	0.294*	
F_4		-	-	-	-	-	-	-	-	-	-	-
F_2		-0.311*	-0.227*	-0.132	-0.309*	-0.29	-0.114	-0.338*	-0.254*	0.345*	0.426*	0.475*
F_3	F.L.m	0.004	0.046	0.06	0.097	0.023	0.122	0.165	0.178	0.014	0.529*	0.17
F_4		-0.206	-0.026	-0.045	-0.137	0.013	-0.336*	0.149	0	-0.375*	-0.127	

*** indicate significant at 0.05 probability level. BW= Boll weight, SCY/P= Seed cotton yield/plant, LCY/P= Lint cotton yield/plant, LP= Lint percentage, SI= Seed index, L/S= Lint/seed, S/B= Seeds/boll, B/P= Bolls/plant, FL= Fiber length, FS= Fiber strength, MIC= Micronaire reading and UI= Univormity index**

On the same trend, seed cotton yield/plant showed significant positive correlation coefficients with lint yield and boll/plant in F_2 generation, but it recorded desirable association with the other yield components in the later generation. Strong association for such traits with high heritability showed possibility of simultaneous improvement of these traits using different selection procedures. These results are in agreement with those obtained by Iqbal *et al* (2006) Desalegn *et al* (2009), Arauju *et al* (2012) Farooq *et al* (2014) and El-Mansy (2015). Boll/plant recorded significant negative association with boll weight across three generations, in the same time the latest trait showed negative correlation with boll components. Thus the cotton breeder deals with intensive selection for within boll to improve yield in cotton. A positive correlation was existed among fiber length and strength. Some relations were changed over generations. This was due to selection procedures which lead to change in gene frequency and increase additive genes (El-Mansy 2009 and Ramadan *et al* 2014).

The F_2 and F_3 for a population were evaluated for yield and fiber traits to the classical selection index according to Smith (1936) and Hazel (1943). Eleven selection indices containing two or more traits simultaneously were constructed in F_2 population besides direct selection for lint yield and other component only. Predicted and realized genetic advances from different selection procedures are presented in Table (3). The data revealed that ten out of eleven selection indices were more efficient than direct selection for improvement of lint yield in F_2 population. The highest predicted genetic gain from F_2 generation for lint yield/plant was observed when selecting for lint yield/plant with bolls/plant (I_{W1}) followed by (I_{W23}, I_{W123}, I_{W12}, I_{W2} and I_{W13}) selecting for lint yield/plant with lint/seed also lint/plant with boll/plant and selection index in involving lint yield/plant with seeds/bolls. These indices give (121.233, 115.54, 115.54, 115.48 and 115.3%) relative efficiency over selection based on lint yield. This was true since lint yield showed positive correlation with the other yield contributing traits. On contrast the lowest predicted genetic advance for lint yield/plant in F2 was observed when selecting for lint/ seed followed by selection for seeds/boll and Selection index involving seeds/boll and lint/seed such traits showed negative loading with lint yield. Similar results were obtained by El-Mansy (2009) and El-Lawendey and El-Dhan (2012).

Table 3. Predicted and actual gain from the different selection procedures for improving lint yield/plant in F_2 and F_3 generations.

Selection procedures	Predicted F_2			Actual F_3		
	i	ii	iii	i	ii	D
	Pred F_2	SA%		ACT		
$I._{W123}$	27.00091	115.5366	157.6685	17.0949	73.14891	9.90601
$I._{W12}$	26.91656	115.1757	157.176	16.63379	71.17583	10.28276
$I._{W13}$	26.94912	115.315	157.3661	15.24054	65.2141	11.70858
$I._{W23}$	27.00131	115.5383	157.6708	17.16178	73.43507	9.839529
$I._{123}$	25.88976	110.782	151.1801	16.79512	71.86613	9.094645
$I._{W1}$	28.33226	121.2334	165.4428	14.31563	61.25644	14.01662
$I._{W2}$	26.98743	115.4789	157.5898	16.6028	71.04322	10.38463
$I._{W3}$	26.77982	114.5906	156.3775	17.02332	72.8426	9.756501
$I._{12}$	25.98035	11.1697	151.7091	14.06178	60.17021	11.91858
$I._{13}$	25.39149	108.6499	148.2705	14.51563	62.11224	10.87586
$I._{23}$	2.835091	12.13132	16.55517	4.697669	20.10128	-1.86258
X_W	17.12511	73.27817	100.00	19.58858	83.81935	-2.46347
X_1	16.22307	69.41837	94.73267	15.01713	64.25813	1.205949
X_2	1.790605	7.661983	10.45602	6.452209	27.60894	-4.6616
X_3	-2.10824	-9.02115	-12.3108	6.061777	25.93828	-8.17002

i Predicted and actual gains as lint yield (g)/plant.
i i Predicted and actual gains percentage as estimated from generation mean.
i i i Predicted and actual gains as percentage of the response of pedegree selection.

The highest actual genetic gains from F_3 generation for lint yield/plant occurred when selecting directly for lint yield/plant. However the indices I_{W23} **(**Selection index involving lint yield/plant, seeds/boll and lint/seed) followed by I_{W123} and I_{W3} (Selection index involving lint yield/plant, bolls/plant, seeds/boll and lint/seed and selection index involving lint yield/plant and lint/seed) were superior to all selection procedures in amount of actual gain.

Most indices showed high discrepancy between predicted and actual genetic gain as lint yield/plant, this was due to non-additive gene effect and large effect of environmental factor. On the other side, some indices showed close agreement between predicted and actual response to selection since the deviation of actual advance from predicted advance was positive and of low value. This may due to the non-additive effects which were relatively low or of minor importance and the additive effects would appear to be predominant. Similar results were obtained by El-Mansy (2009), El-Lawendey and El-Dahan (2012) and El-Mansy (2015).

Table 4. Predicted and actual gain from the different selection procedures for improving lint yield/plant in F_3 and F_4 generations.

Selection procedures	Predicted F_3			Actual F_4			Predicted F_4		
	i	ii	iii	i	ii	D	i	ii	iii
$I._{w123}$	17.20	52.48	108.43	11.81	36.04	5.39	20.93	59.03	128.60
$I._{w12}$	17.08	52.10	107.63	11.18	34.10	5.90	20.86	58.84	128.17
$I._{w13}$	17.20	52.46	108.38	10.00	30.50	7.20	20.92	59.02	128.57
$I._{w23}$	17.04	51.97	107.37	8.52	25.98	8.52	20.63	58.20	126.79
$I._{123}$	17.13	52.25	107.94	6.52	19.88	10.61	20.32	57.32	124.86
$I._{w1}$	17.34	52.89	109.28	14.49	44.21	2.85	23.51	66.33	144.49
$I._{w2}$	17.03	51.97	107.37	11.03	33.66	6.00	20.70	58.40	127.22
$I._{w3}$	17.03	51.96	107.36	10.14	30.94	6.89	20.60	58.11	126.59
$I._{12}$	17.06	52.05	107.54	7.02	21.40	10.05	20.25	57.11	124.42
$I._{13}$	15.63	47.69	98.54	10.00	30.50	5.64	19.71	55.60	121.11
$I._{23}$	5.23	15.95	32.95	-4.78	-14.57	10.00	15.82	44.63	97.22
X^W	15.87	48.40	100.00	9.40	28.69	6.46	16.27	45.90	100.00
X_1	14.59	44.51	91.95	10.00	30.50	4.59	15.56	43.91	95.65
X_2	4.84	14.75	30.48	-3.48	-10.60	8.31	-12.51	-35.29	-76.88
X_3	4.36	13.29	27.46	-4.13	-12.59	8.48	3.91	11.02	24.00

i Predicted and actual gains as lint yield (g)/plant.
i i Predicted and actual gains percentage as estimated from generation mean.
i i i Predicted and actual gains as percentage of the response of pedegree selection.

Maximum predicted and actual genetic advance from F_3 and F_4 generation for lint yield/plant were achieved when selecting for lint yield/plant and bolls/plant followed by selection indices containing lint yield/plant, boll/plant, seed/boll and lint/seed as well as selecting for bolls/plant and lint/seed, these main attributes of lint yield. On the other side, the lowest predicted and realized genetic gains for lint yield/plant were observed when selecting for lint/seed followed by pedigree selection for seed/boll and selection index involving seeds/boll and lint/seed respectively.

Deviations of the actual genetic advance from the predicted advance from F_3 and F_4 generations were positive in all cases. These deviation were large values for some procedures, such large discrepancy between predicted and actual gains did not raise doubt as to the validity of the general theory of selection index and also due to the large effect of genotypic x environment interaction. These results are in good agreement with those obtained by El-Mansy (2015) and Abd El-Aty *et al* (2017).

It is worthy to conclude that, selection including single trait is not efficient to bring genetic improvement in cotton yield. This is due to the fact that yield is a commutative effect of several traits and hence selection for single traits only is not expected to explain fully genotypic variation for yield. However, when two or more traits based indices were merged, the relative efficiency of the result index is better than using each of single trait independently, since the obtained gains are distributed among all evaluated traits and achieved a higher total without a significant loss in the main traits (El-Mansy 2015).

The data illustrated in Table (5) indicate that direct selection for lint yield/plant and selection index involving lint yield/plant, seeds/boll and lint/seed gave high values of realized advance for bolls/plant, seeds/boll and lint/seed (selected traits) and most yield traits.

Table 5. Actual response to selection by using different selection procedures estimated from F_3 means for the selected and unselected traits.

indexes	B.W.	S.C.Y./P.	LP%	B/P	S/B	S.I.	L/S	Mic.	F.S.	U.R.%	F.L.mm
$I._{w123}$	0.41	41.77	1.56	9.59	3.12	2.25	0.0179	-0.04	0.72	3.38	1.04
$I._{w12}$	0.39	40.37	1.63	9.38	2.99	2.17	0.0176	-0.07	0.77	3.54	0.99
$I._{w13}$	0.44	36.81	1.58	8.10	3.05	2.27	0.0180	-0.07	0.81	3.44	1.02
$I._{w23}$	0.44	42.27	1.45	9.51	3.33	2.34	0.0181	-0.08	0.76	3.42	1.10
$I._{123}$	0.41	42.79	0.83	10.14	2.99	2.23	0.0154	-0.14	0.67	3.41	0.89
$I._{w1}$	0.30	37.32	0.44	9.45	2.64	1.93	0.0123	-0.25	0.65	3.52	0.83
$I._{w2}$	0.45	40.46	1.56	8.96	3.24	2.35	0.0185	-0.13	0.70	3.42	1.07
$I._{w3}$	0.46	41.64	1.54	9.19	3.22	2.39	0.0187	-0.07	0.71	3.25	0.98
$I._{12}$	0.38	35.11	1.15	8.19	3.34	2.26	0.0165	-0.04	0.81	3.84	0.85
$I._{13}$	0.34	37.61	0.55	9.20	2.71	2.05	0.0134	-0.18	0.67	3.47	0.72
$I._{23}$	0.35	11.05	0.58	0.78	3.19	2.21	0.0146	-0.18	0.78	3.14	1.04
$I._{xw}$	0.54	48.08	1.69	10.61	3.44	2.61	0.0204	-0.06	0.71	3.41	0.99
$I._{x1}$	0.36	38.77	0.63	9.38	2.97	2.18	0.0143	-0.16	0.74	3.53	0.91
$I._{x2}$	0.39	15.50	0.78	1.96	3.44	2.31	0.0158	-0.15	0.77	2.96	1.16
$I._{x3}$	0.46	11.50	2.08	0.31	2.34	2.41	0.0205	-0.27	0.66	3.62	0.36

BW= Boll weight, SCY/P= Seed cotton yield/plant, LCY/P= Lint cotton yield/plant, LP= Lint percentage, SI= Seed index, L/S= Lint/seed, S/B= Seeds/boll, B/P= Bolls/plant, FL= Fiber length, FS= Fiber strength, MIC= Micronaire reading and UI= Univormity index

There were a close agreement between lint yield /plant and selected traits. These data indicate that advanced generations were highest in means for three selected traits about F_2 generation and get up response fast in improvement through advanced progeny (F_3). Most indices give high actual advances in F_3 generations in three selected traits. This trend was changed in F_4 generation since the maximum actual gain was obtained for boll/plant when applied indices involved lint yield/plant and bolls/plant and index involving lint yield/plant, bolls/plant, seeds/boll and lint/seed. However, maximum actual gain for seed/boll was recorded with selection for seeds/ boll and selection index involving seeds/boll and lint/seed.

The actual advance determined from F_3 generation (Table 6) was higher than from F_4 generation for all indices. Indices $I._{W1}$, $I._{W123}$ and I_{W2} caused high improvement in seed cotton yield/plant estimation from F_4 generations.

Table 6. Actual response to selection by using different selection procedures estimated from F_4 means for the selected and unselected traits.

indexes	B.W.	S.C.Y./P.	LP%	B/P	S/B	S.I.	L/S	Mic.	F.S.	F.L.mm
$I._{w123}$	-0.136	30.163	0.341	10.366	-2.526	-0.160	0.000	-0.171	0.189	0.194
$I._{w12}$	0.097	27.708	0.675	7.788	-1.371	0.018	0.002	-0.083	0.001	-0.039
$I._{w13}$	0.014	24.547	0.689	7.513	-1.924	-0.096	0.002	-0.213	0.128	0.428
$I._{w23}$	0.172	20.814	0.639	5.163	-0.990	0.138	0.003	-0.055	0.053	0.144
$I._{123}$	0.222	14.847	1.114	3.355	0.001	-0.229	0.002	-0.121	0.295	-0.289
$I._{w1}$	-0.086	37.714	0.147	12.205	-1.999	-0.021	0.001	0.045	0.028	-0.622
$I._{w2}$	-0.036	28.405	0.230	8.871	-2.515	-0.021	0.001	-0.171	0.095	0.336
$I._{w3}$	-0.069	23.738	1.205	7.830	-2.457	-0.004	0.004	-0.180	0.362	0.269
$I._{12}$	-0.069	18.022	0.105	6.196	-1.565	-0.046	0.000	-0.138	0.120	0.211
$I._{13}$	0.014	24.547	0.689	7.513	-1.924	-0.096	0.002	-0.213	0.128	0.428
$I._{23}$	0.375	-14.003	0.786	-6.323	1.862	-0.060	0.002	-0.083	0.434	-0.028
$I._{xw}$	-0.103	22.003	1.110	7.601	-2.682	-0.091	0.003	-0.265	0.392	0.581
$I._{x1}$	0.014	24.547	0.689	7.513	-1.924	-0.096	0.002	-0.213	0.128	0.428
$I._{x2}$	0.497	-11.804	1.480	-6.329	2.135	-0.237	0.003	-0.105	0.965	-0.172
$I._{x3}$	0.139	-11.995	0.522	-4.570	1.435	-0.421	-0.001	-0.296	0.220	0.294

BW= Boll weight, SCY/P= Seed cotton yield/plant, LCY/P= Lint cotton yield/plant, LP= Lint percentage, SI= Seed index, L/S= Lint/seed, S/B= Seeds/boll, B/P= Bolls/plant, FL= Fiber length, FS= Fiber strength, MIC= Micronaire reading and UI= Univormity index

High actual genetic advances in lint percentage and seed index recorded via selection indices $I._{W3}$, Ex. and $I._{X3}$ were higher than other indices. Generally the actual advance decrease in F_4 as compared with F_3 generations for unselected traits. Improvements in selected and unselected traits were very high in magnitude and fast through advanced generations. The F_4 generation gave a smaller improvement compared with each of F_2 and F_3 generations to reach stability point and homogeneity between different families (Table 7).

Segregating populations could be assessed using means and variability along with their ability to release superior segregates to know the real worth of population. Breeder really to develop high yielding with acceptable fiber quality lines.

Table 7. Predicted gains from selection

F_3	B.W.	S.C.Y./P.	LP%	S.I.	Mic.	F.S.	U.R.%	F.L.mm
L.C.Y.	0.172	43.971	0.387	0.520	0.065	0.069	0.292	0.139
B / P	-0.052	40.688	-0.173	-0.117	0.053	0.086	0.295	0.053
S / B	0.352	13.981	-0.396	1.092	-0.080	0.033	-0.162	0.249
L / S	0.423	7.901	1.957	1.347	0.002	0.007	0.293	0.384
F_4	B.W.	S.C.Y./P.	LP%	S.I.	Mic.	F.S.	F.L.mm	
L.C.Y.	-0.188	43.051	-0.334	0.6376	0.1983	-0.34	-0.81	
B / P	-0.32	42.458	-0.825	0.4415	0.1691	-0.359	0.0233	
S / B	0.2976	-32.08	-0.087	-0.721	-0.117	0.3367	-0.575	
L / S	0.1025	4.9717	2.0554	0.8228	0.161	0.0351	0.0001	

In the present study the scope of superior segregates were isolated on the basis of various selection procedures, then the five selected families were isolated in F4 generation by superiority of these families from better parents, F3 families and point start of F2 plants mean. Data presented in Table (8) revealed that all selected families exceeded better parent and point start of F2 means, however some of these families surpassed F3 families mean for yield traits as well as fiber quality traits. The breeder may utilize such selected families in breeding programs aiming to improve yield and quality.

Table 8. The best selected families resulted from different selection procedures in F_4 generation.

Family No.	B.W.	S.C.Y./P.	L.Y.	LP%	B/P	S/B	S.I.	L/S	Mic.	F.S.	F.L.mm
1	3.5	101.33	42.4	39.2	32.7	16.6	11.0	0.071	3.6	10.5	34.4
2	3.6	90.73	37.9	41.8	23.9	18.3	12.5	0.092	3.8	11.5	33.5
3	3.3	97.7	39.2	40.1	29.6	17.0	11.8	0.079	4.0	10.0	33.6
5	4.0	93.7	38.4	41.0	23.4	20.7	11.9	0.083	3.9	10.0	34.2
9	3.7	88.3	34.4	38.9	23.9	19.9	12.2	0.078	4.0	10.8	33.6

BW = Boll weight, SCY/P = Seed cotton yield/plant, LCY/P = Lint cotton yield/plant, LP = Lint percentage, SI= Seed index, L/S = Lint/seed, S/B = Seeds/boll, B/P = Bolls/plant, FL = Fiber length, FS = Fiber strength, MIC= Micronaire reading and UI = Univormity index

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استخدام دلائل الانتخاب لتحسين بعض الصفات الاقتصادية فى القطن المصرى

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يعتمد اختيار طرق الانتخاب بالتحسين الوراثى للقطن إلى حد كبير على نوع ومقدارالتباين الوراثي في العشيرة. وقد استخدام الجيل الثانى والثالث والرابع من الهجين (جيزة ٨٦ x بيما س٦) والتى تمت زراعتها فى محطة البحوث الزراعية بسخا خلال الثلاث مواسم ٢٠١٦ و ٢٠١٧ و ٢٠١٨ . وذلك بهدف دراسة امكانية استخدام دلائل الانتخاب ومقارنتها بالانتخاب المباشر وغير المباشر لتحديد أفضل العائلات و تقدير التحسين الوراثى الفعلى والمتوقع لطرق الانتخاب المستخدمة و بالاضافة الى معرفة التحسين المرتبط بين الصفات وبعضها. وبمقارنة متوسطات الصفات المختلفة بين الأجيال الثلاثة F_2 و F_3 و F_4 أظهرت النتائج زيادة فى المتوسط لجميع الصفات بالتدرج من الجيل الثانى إلى الجيل الرابع باستثناء قراءة ميكرونير (القيم المرغوبة). كان PCV و GCV عمومًا أكبر في الأهمية بالنسبة لجميع الصفات المدروسة في الجيل F_2 مقارنةً بالأجيال المتقدمة F_3 و F_4. مما يدل على أهمية التباين الوراثى مما يعطى فرصة لنجاح الانتخاب فى الأجيال المبكرة. كانت قيم كفاءة التوريث تزيد عن ٥٠٪ لمعظم الصفات المدروسة للأجيال الثلاثة ، مما يشير إلى وجود درجة عالية من التباين الوراثي في الأجيال المبكرة. كانت هناك ارتباطات معنوية مرغوبة بين وزن اللوز وكل من عدد البذور/اللوزة ، ومعامل البذرة وكمية الشعر/البذور عبر الأجيال الثلاثة. كان التحسين الوراثى المتوقع والفعلى بالانتخاب المحسوب من دلائل الانتخاب المختلفة يشير الى أن عشرة من بين ١١ دليل انتخاب كانت أكثر كفاءة من الانتخاب المباشرلتحسين محصول الشعر فى عشيرة الجيل الثانى. لوحظ ان افضل نتائج متحصل عليها لتحسين محصول الشعر/نبات فى الجيل الثانى عند استخدام الدلائل الانتخابية دليل انتخاب لتحسين محصول القطن الشعر/النبات الجيل F_2 كان عند استخدام انتخاب محصول الشعر/نبات مع عدد اللوز/النبات (IW1) متبوعًا بـ (IW23، IW123، IW12، IW2 و IW13) الانتخاب لمحصول الشعر / النبات معمحصول الشعر/البذرةوأيضا محصول الشعر/النبات مع اللوز/النبات ودليل محصول

الشعر/النبات معدد البذور/اللوزة. على النقيض من ذلك ، لوحظ أق لتحسين وراثى متوقع فى الجيل الثانى لمحصول الشعر/نبات عند الانتخاب لمعامل الشعر يليه الانتخاب لعدد البذور/اللوزة والدليل الانتخابى الذى يشمل معامل الشعر مع عدد البذور/اللوزة. أظهرت النتائج أن أعلى تحسين وراثي فعلي فى الجيل الثالث لصفة محصول الشعر/النبات عند الانتخاب المباشر لنفس الصفة. بينما اعطت دلائل الانتخاب لمحصول الشعر/النبات مع عدد البذور/اللوزة و معامل الشعر IW23 اعلى قيمة للمحصول الوراثى المتوقع لصفة محصول القطن الشعر متبوعًا بIW123 و IW3 (دليل الانتخاب لمحصول الشعر/النبات معدد اللوز/النبات و عدد البذور/اللوزة ،ومعامل الشعر) و (دليل انتخاب لصفة محصول الشعر مع معامل الشعر) على التوالى. اعلى قيم للتحسين الوراثى المتوقع والفعلى للجيلين الثالث والرابع لصفة محصول القطن الشعر عند الانتخاب لمحصول الشعر/النبات مع عدد اللوز/النبات متبوعا بدلائل الانتخاب التى تشمل صفات محصول الشعر/النبات وعدد اللوز/النبات وعدد البذور/اللوزة ومعامل الشعر. لوحظ أن العائلات المنتخبة والتى تفوقت على الأب الأفضل ومتوسط الجيل الثانى والتى كان بعضها متفوقا أيضاعلى متوسط الجيل الثالث صفات المحصول القطن وعلى هذا يمكن للمربى استخدام نتائج هذه الدراسة فى ادراج العائلات المنتخبة فى برامج التربية والتى تهدف لتحسين المحصول والجودة.

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